INT. J. BIOL. BIOTECH., 9 (3): 161-190, 2012.

PLANT SIZE-FECUNDITY RELATIONS IN *THESPESIA POPULNEA* (L.) SOL. EX. CORR. GROWING UNDER ARID–SALINE CONDITIONS IN KARACHI, PAKISTAN

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ABSTRACT

Twenty five *T. populnea* (L) Sol. ex. Corr. plants (1.2 to 5m in height) cultivated in saline soils of EC_e: 1.56 to 64.7 dS^{-1} were studied for various morphometric and fecundity parameters. The plants were generally monostemmic and stem size varied from 2.5 to 32.8 cm in diameter. The highest number of capsules produced by any plant studied was 2600. The number of capsules produced in autumn were on an average 1.57 times to that of the spring. The number of seeds per capsules varied from 6.0 ± 0.39 to 15.2 ± 0.62 and averaged to 11.85 ± 0.174 (8 – 18). Average seed mass per capsule ranged from 0.99 ± 0.053 to 2.31 ± 0.07 g. Mean individual seed mass was 135.99 ± 0.3719 mg ranging from 20 to 300 mg – a 15-fold variation. The seed mass distribution was leptokurtic and negatively skewed. The fecundity varied greatly from plant to plant (6 – 29822 seeds per plant). The trees of stem diameter size-class of 20-25 cm were more productive. Average Seed yield in mature trees was 1.25 ± 0.2169 kg and varied c 86.4%. There was a great degree of multi-colinearity among vegetative and reproductive parameters. Allometric relationships were developed between vegetative morphometric parameters of the plants and their fecundities. The best predictive equation of fecundity (SN, number of seeds per plant) with stem diameter (SD) was as follows:

$$\text{Loge SN} = -2.79171 + 3.78597 \text{ Loge SD} - 1.2763 (\text{Loge SD})^2 \pm 0.7008$$

t = - 2.72   t = 7.18   t = - 4.93

p < 0.001   p < 0.001   p < 0.001

$R^2 = 0.9104$; Adj. $R^2 = 0.9021$; F = 111.78

Key-words: Size-fecundity relations, *Thespesia populnea*, arid-saline conditions, Karachi.

INTRODUCTION

Studies on plant allometry aim to uncover size-correlated variations in organic form and process (Huxley, 1932). A broad variety of plants have been found to follow well-defined allometric patterns resulting as a consequence of natural selection and adaptive evolution (Niklas, 1994). Allometric relations are often based on data from mature plants (Gould, 1966; Niklas, 1994). The utility of such relations is immense as they may be used to estimate plant parameters that are difficult to measure, such as total biomass, root biomass, etc. Most of the examples of allometric investigations are related to tree species (Whittaker and Woodwell, 1968; Andersson, 1971; Ek, 1979; West *et al.,* 1989; Reddy *et al.,* 1998). Allometric relations have generally been treated as genetically fixed characteristics of plant species (Weller, 1987) or as a feature of some related species as a group (Niklas, 1995). Allometric differences may thus be expected with even cultivars of a species. The ability of plants to adapt to the environmental conditions, especially in case of annual plants, is reported to significantly modify the allometric relationships (Reeke and Bazzaz, 1987; Weiner and Thomas, 1992). The conditions of growth may also modify the allometric relationships in plants e.g., the allometric parameters of harvest index (ratio of seed mass to the above-ground plant biomass) is reported to vary over broad range of environment and peculiarities of the growing conditions (Mayers *et al*., 1991; Prior and Rogers, 1995). The knowledge of allometric relationships is, obviously, very useful in agriculture and afforestation.

Thespesia populnea (L.) Sol. Ex. Corr. (Cork tree, Milo, Umbrella tree, Indian tulip tree), a coastal and moderately to highly salt tolerant multipurpose plant in tropical countries, is a valuable plant. In Pakistan, it is confined to coastal region particularly Karachi. – cultivated in parks or along roadside as ornamental or a shade plant (Abedin, 1979). It occurs in association with mangrove species on East Coast of India (Satyanarayana *et al.*, 2002). It can tolerate high salinity (up to 2.0%) (Sun *et al.,* 2004), and is also reported to be tolerant to 10g diesel/ Kg of soil alone or in combination with 1% salt. Khan and Shaukat (2009) have also reported that *T. populnea* can grow in diesel polluted soil (up to around 1.0%) with some reduction in growth in arid environment of Karachi. It is preferably raised with seeds as then the timber is knot free, straight, even-grained and tough. The seeds of this plant are known to contain oil but not used on commercial scale. It is reported to be capable of growing in soil of varying textures and chemical compositions. The present study is carried out to estimate seed yield of *T. populnea* and develop allometry for seed yield relationship with plant morphometric characteristics under saline-arid environment of Karachi.

Description of the area

Climatic Peculiarities: The climate of Karachi is of BWh type and bio-climate type as determined by Holdridge's system falls in the category of Tropical Bush Formation (Qadir *et al*., 1966). The rainfall is irregular and averages below 200mm mostly received in summer (Khan *et al*., 2006a). Annual evapo-transpiration is 1750 mm (Zubenok, 1977). Summer (May-October) and winter (November-April, are two climatic extremes. Solar radiation is maximum in summer months of May and June and substantially lower in winter months (Ahmad *et. al*., 1991).

MATERIALS AND METHODS

Soil Analysis: The surface and subsurface (0-30 and 30-60 cm deep, respectively) soil samples collected from underneath the sample plants were analyzed for their salinity status, pH and cationic content (Na and K) as per standard methods of USDA (1956).

Morphometric Analysis: Twenty-five healthy, undisturbed and open-grown variously sized *T. populnea* plants grown in saline soils or raised under saline water irrigation, in Karachi (in areas of Hawkes Bay, Nazimabad, Regent Plaza area, Boat-Basin (Clifton) and Karsaz) were studied for various morphometric parameters such as height (H), stem diameter (SD, at 50 cm from the ground), number of major laterals (L) and their sizes, crown length and other canopy dimensions. Since *Thespesia* plants exhibited bimodality in flowering, their fecundity i.e., production of floral buds, flowers and capsules were counted in spring and then again in autumn as well.

The capsules are initially green in colour. They turn to green brown, to brown to dark brown with maturity and shrink and dehydrate in later stage. The capsules are retained by the plant for considerable period of time and the current season capsules may easily be identified from last season capsule crop. The capsules are not provided with any efficient means of dehiscence or dispersal. A sizeable number of capsules were collected from sample trees and stored in laboratory till further analysis.

The crown of the plants exhibited two forms – younger plants were spherical in canopy outline and mature ones exhibited more or less hemi-spherical canopy. Basal area (BA) of the plants was determined as BA = $\sum_{i=1}^{n}$ (di^2.Π) / 4, where di is the diameter of its ith stem (Khan *et. al.*, 1986). The projected crown area was estimated as A = Πr^2 where r is the radius of the crown measured horizontally along two radii at right angle. Canopy volume was estimated as the volume of a sphere in case of spherical canopies that is (CV = 4/3 Πr^3) and half of a sphere volume i.e., CV = 2/3 Πr^3) in case of hemi-spherical canopies, where r is average radius of the canopy i.e., average of two horizontal radii of canopy at right angle and the projected radius vertically with the help of crown length. In case of spherical canopies crown length was roughly of the order of the horizontal canopy diameter and in case of hemi-spherical crown, crown length was generally comparable to the horizontally–measured canopy radius.

The Live Crown ratio (LCR) was calculated as crown length / total tree length (Hocker, 1979). To obtain an integrative index reflective to plant architecture, a complexity index (Ci) for each plant was calculated as H x number of main stems x LB x BA x canopy diameter (CD) x crown length (CH) x mean lateral branch diameter x 10^{-3}, following the practice of Pool *et al.* (1977).

The plants were stratified on the basis of stem diameter as given below to generalize and correlate the size impact on various variables.

Size (age) Classes	Stem diameter (cm)	Plants Representative to the size class (Acronyms as per Table 1)
A	< 10	HB1, HM, N4, N5, K3, GL
B	10 – 15	B4, B5, B6, B7, K1, HB1, CL
C	15 – 20	R2, R3, R4, R5, B1, B2, B3, N1
D	20 – 25	N2, K2
E	> 25	R1, N3

Estimation of Seed Crop: To estimate seed crop per plant in terms of the number of seeds per plant (SN) and seed yield per plant in terms of seed mass (SY), distribution pattern of seeds among capsules and individual seed weight distribution were followed to arrive at statistically valid coefficients (MNS_{cpi} and MSW_i) needed in the following formulae.

$SN = CP_i \times MNS_{cpi}$

$SY = SN \times MSW_i$, where

CP_i is the number of capsules produced by the i^{th} plant – (known by counting)

MNS_{cpi} is the mean number of seeds in capsules of the i^{th} plant, and

MSW_i is the mean seed weight of the i^{th} plant

1) Variation of Number of Seeds among Capsules: Thirty air-dried capsules from each mature tree (600 capsules in all) were opened to determine number of seeds enclosed within each of them. Relatively younger plants were excluded from this analysis owing to the insufficient number of capsules available with them. Location and dispersion parameters of the data were calculated to follow the distribution pattern.

2) Variation of total seed mass in a capsule: The air-dried seed mass recovered from a capsule was recorded for 30 capsules of each plant except sample tree, HM of Hawkes Bay, only 15 capsules of which could be studied. The distribution patterns of the seed mass within capsules of an individual tree or for the composite sample of 585 capsules of all 20 trees were characterized with location and dispersion parameters.

3) Variation of Individual Seed Weight: The air-dried seeds recovered from the capsules were weighed individually on an electrical balance and seed size distribution was followed within each sample plants. A few seeds of less than 10 mg in mass were considered too small and excluded from the seed size distribution analysis. The general pattern of seed size distribution was, therefore, based on seed mass data of 6899 seeds – a pooled lot from all sample plants.

Allometric relationship among Vegetative Morphometric Parameters and the seed crop: The allometric relationships of plants' vegetative morphometric parameters amongst themselves and with seed crop parameters (SN and SY) were investigated statistically by employing correlation and regression analysis.

OBSERVATIONS AND RESULTS

Salinity status: The results of analysis of surface and subsurface (0-30 and 30-60 cm deep) soil samples are presented in Table 1. The surface salinity ranged from $2.22 dS.m^{-1}$ to $166.7 dS.m^{-1}$ – generally higher on the surface presumably due to evaporation from surface of the soil. The highest salinity was encountered with a sample situated in salt marsh at Hawkes Bay. This plant, however, also received fresh water drained out from a nearby mosque. Plants of Karsaz area associated relatively with higher salinity level (28.7 – 43.93 $dS.m^{-1}$) than plants of Boat Basin area (11.20 – 28.5 $dS.m^{-1}$) or Plants of North Nazimabad (7.7 – 10.20 $dS.m^{-1}$). Na was observed to be much higher in concentration than K in all soil samples. pH varied from 7.8 to 8.8. Soil texture associated with the sample plants was generally fine-textured but more so for Boat basin plants – silt loam to clay loam soils.

Habit and Pattern of Variation in Morphometric Data: *T. populnea* is a moderately sized tree, which may reach 8 -10 m in height. In our studies plants up to 5 m in height and growing in differentially saline conditions (reaching up to $64.7 dS.m^{-1}$), were included. There were some larger trees available but they were either disturbed to varying extent or abounded with non-saline conditions. Plants little higher than 1m in height with stem diameter around 2-3 cm are largely non- reproductive. Few such plants that had entered reproduction (possibly first time) were, however, included in the study in connection with the morphometric measurements. The plants were generally monostemmic except three plants (N3, R1, and K2) which were distemmic in nature (Table 2).

Average values of various structural attributes of the plants are outlined in Table 3. Variability of the morphological parameters was generally moderate (around 30%) but Ci, BA and CP exhibited very high variation (181.4, 104.7 and 100.2%, respectively). The mean Live Crown ratio (LCR) was 0.484 for plants with hemispherical canopy (mature trees with main stem conspicuously visible) and 0.798 for plants with spherical canopy (younger plants – main stem covered with foliage and scarcely visible) - the LCR ratio between the two being 0.57:1.0.

Table 1. Soil characteristics associated with the *Thespesia populnea* trees growing in the saline environment.

Soil Properties	*T. populnea Trees*									
	HB1*	HM	N1	N2	N3	CL	B1	B2	B3	B4
ECe (dS.m-[1])										
A**	2.2	166.7	11.9	7.85	7.7	13.90	47.00	34.0	26.8	43.00
B	1.6	24.0	10.5	R	R	7.10	16.60	27.2	31.7	13.50
C	0.9	4.0	8.10	R	R	-	13.50	9.4	26.9	11.20
Mean	1.56	64.7	10.20	7.85	7.7	10.5	25.7	23.53	28.5	21.90
pH										
A**	8.55	7.5	6.25	7.85	8.05	8.5	8.75	8.75	8.5	8.65
B	8.45	8.4	7.4	R	R	8.15	8.6	8.5	8.85	8.85
C	8.1	8.25	8.25	R	R	-	8.8	8.7	8.5	8.45
Mean	8.37	8.05	7.3	7.85	8.05	8.37	8.7	8.65	8.6	8.65
Soil Texture *** (0 – 60 cm profile)										
0-60 cm profile	SL	S - CLL	L	L	L	SLT	SL - CLL	SL - CLL	SL - CLL	STL-CLL
Cations (meq /l) (0 – 60 cm profile)										
Sodium	-	-	54.35	30.43	141.3	130.4	304.3	391.3	347.8	108.7
Potassium	-	-	8.33	8.33	31.4	17.4	5.13	30.13	28.2	24.4

Soil Properties	***T. populnea Trees***									
	B5	B6	B7	R1	R2	R3	R4	R5	K1	K2
ECe: dS.m-[1]										
A**	8.90	46.00	41.00	11.40	8.20	10.00	5.30	6.10	26.70	72.50
B	13.50	15.10	21.50	9.20	8.00	11.30	10.30	9.10	31.70	28.50
C	11.20	11.60	18.70	12.20	7.00	12.30	9.60	7.90	26.90	30.80
Mean	11.20	24.20	27.10	10.90	7.73	10.30	8.40	7.70	28.7	43.93
pH										
A	8.55	8.85	8.8	8.6	8.75	8.65	8.65	8.65	8.4	7.65
B	8.45	8.7	8.55	8.0	8.5	8.65	8.55	8.45	8.25	7.6
C	8.35	-	8.05	8.35	8.7	8.05	8.00	8.15	7.95	8.05
Mean	8.45	8.8	8.5	8.32	8.65	8.38	8.40	8.4	8.2	7.8
Soil Texture (0 – 60 cm profile)										
0 – 60 cm Profile	STL-CLL	STL-CLL	STL - CLL	L	L	L	L	L	L	L
Cations (meq / l) (0 – 60 cm profile										
Sodium	391.3	-	413.04	130.4	76.09	-	76.09	76.09	336.96	380.43
Potassium	89.7	-	85.9	36.5	27.6	-	24.4	19.9	14.8	-

*, Locality- HB1, Hawkes Bay sample1, HM, Hawkes Bay sample near Mosque, N1 – N3, North Nazimabad samples 1-3, CL, Clifton; B1-B7, Boat Basin samples 1-7; R1-R5, Rimpa Plaza area samples 1-5 and K1-K2, Karsaz samples 1-2. ECe, pH and cations are based on saturated soil extract. ** A, surface sample; B, 30 cm deep; C, 60 cm deep. ***, L, Loam; SL, Sandy Loam; SLT; Silty; STL, Silt Loam; CLL, Clay Loam; R, Rock.

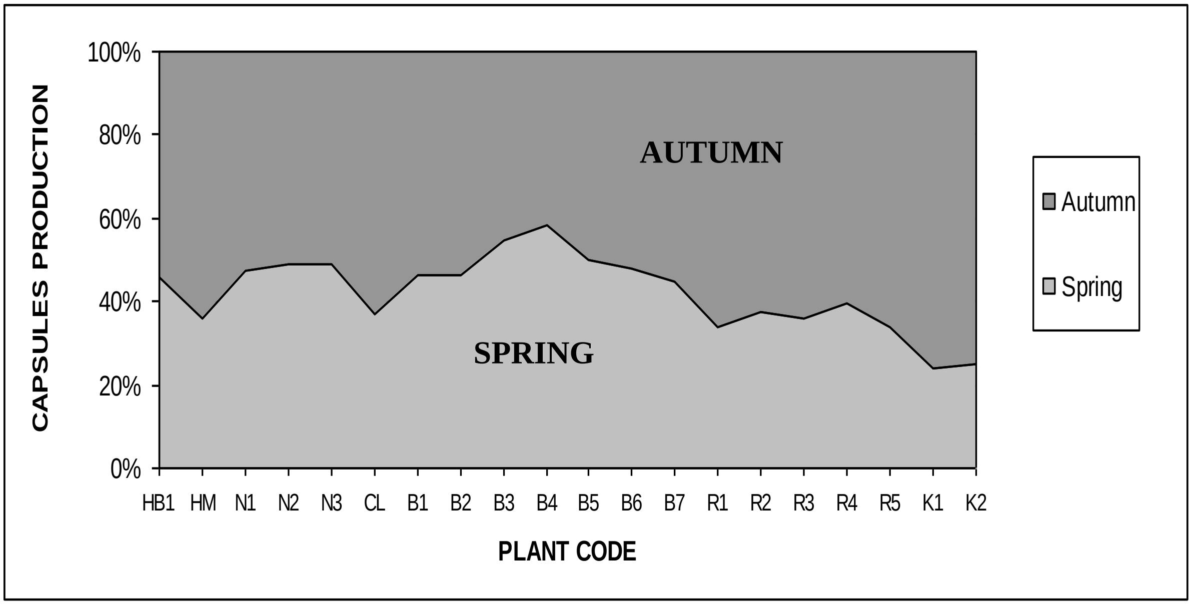


Fig.1. *Per cent* Capsule production in autumn and spring in mature trees of *T. populnea* growing under saline environment in Karachi. Acronyms are the same as given in Table 1 or 2.

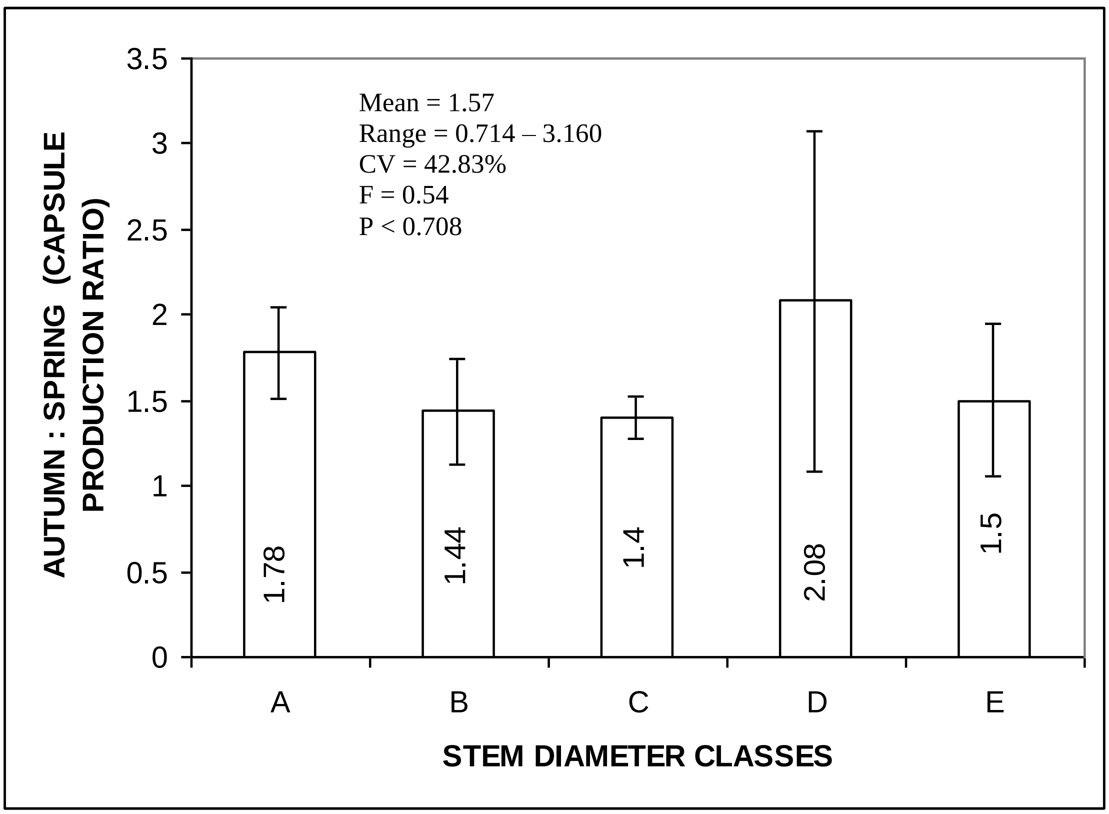


Fig.2. Average autumn: spring capsule production ratio as affected by the tree size of *T.* populnea growing under saline conditions in Karachi. Key to the size classes of stem diameter – A, < 10cm; B, 10 – 15 cm; C, 15 – 20 cm; D, 20 – 25 cm; E, > 25 cm.

Table 2. Morphometric data of *Thespesia populnea* trees growing under saline environment in Karachi.

Parameters	*T. populnea* Trees												
	HB1☼	HB	HM	N1	N2	N3	N4	N5	CL	B1	B2	B3	B4
Height, H (m)	4.5	1.25	3.0	3.65	4.47	4.26	1.20	1.31	3.65	5.0	4.8	3.96	3.40
Number of main stems	1	1	1	1	1	2	1	1	1	1	1	1	1
SD (Stem ,cm)	10.35	2.30	4.94	15.92	24.84	24.2, 22.2 (32.8)*	2.5	2.6	11.78	18.78	17.20	18.79	12.10
Number of Laterals LB)	2	2	3	2	3	3	2	3	3	3	6	3	3
Ø L_1 (cm)	6.2	1.0	4.9	7.3	14.3	5.1	1.2	1.10	7.7	6.0	10.2	11.1	8.6
Ø L_2 (cm)	5.0	1.2	8.1	9.2	12.7	13.4	0.89	1.3	2.6	10.2	8.0	10.8	6.0
Ø L_3 (cm)	-	-	6.0	-	16.9	16.6	-	1.2	3.8	9.6	6.7	7.0	5.8
Ø L_4 (cm)	-	-	-	-	-	-	-	-	-	-	8.0	-	-
Ø L_5 (cm)	-	-	-	-	-	-	-	-	-	-	7.3	-	-
Ø L_6 (cm)	-	-	-	-	-	-	-	-	-	-	6.4	-	-
Mean Lateral Ø (cm)	5.62	1.10	6.34	8.30	14.65	11.70	1.10	1.20	4.70	8.62	7.76	9.63	6.80
Vertical Canopy Height (m)	2.98	1.05	2.78	2.05	2.47	2.56	1.05	1.10	2.43	2.52	2.45	1.76	1.86
LCR	0.67	0.84	0.92	0.56	0.55	0.60	0.88	0.84	0.66	0.50	0.50	0.44	0.55
Horizontal Canopy Ø,CD; m)	2.6	0.98	2.6	2.25	2.75	2.25	0.98	1.0	4.0	3.20	5.8	4.85	3.4
Canopy Volume, CV (m^3)	11.4	0.55	10.2	5.6	9.8	6.8	0.75	0.79	20.6	12.24	45.1	22.4	9.5
Capsules (CP)	552	2	78	380	980	718	2	8	954	2600	923	506	960
Basal Area, BA (cm^2)	84.09	4.2	19.16	198.96	484.36	846.6	4.9	5.3	108.93	276.86	232.23	277.16	114.93
Complexity index (Ci)	32.95	0.012	8.47	55.60	575.83	147533	0.013	0.027	54.50	288.68	737.51	270.7	50.41
Canopy Shape	Sph	Sph	Sph	Sph	Sph	Sph	Sph	Sph	HSph	HSph	HSph	HSph	HSph

Parameters	*T. populnea* Trees											
	B5	B6	B7	R1	R2	R3	R4	R5	K1	K2	K3	GL
Height, H (m)	2.74	2.60	3.50	4.0	4.5	5.0	5.0	5.0	4.0	5.0	1.40	1.45
Number of main stems	1	1	1	2	1	1	1	1	1	2	1	1
SD (Stem Ø, cm)	12.10	10.82	11.15	28.3, 12.0 (30.7)*	16.56	16.58	16.88	17.52	14.33	14.4, 17.8 (22.9)*	3.1	3.5
Number of Laterals (LB)	4	2	3	4	2	3	2	3	3	3	2	3
Ø L_1 (cm)	6.0	7.0	4.8	17.8	9.6	8.0	6.1	11.2	9.3	10.2	1.3	0.9
Ø L_2 (cm)	5.4	8.0	6.1	12.4	14.0	8.6	13.1	8.3	5.6	11.2	1.4	1.0
Ø L_3 (cm)	7.3	-	5.7	6.9	-	6.4	-	5.8	5.9	6.1	-	1.1
Ø L_4 (cm)	5.9	-	-	7.2	-	-	-	-	-	-	-	-
Ø L_5 (cm)	-	-	-	-	-	-	-	-	-	-	-	-
Ø L_6 (cm)	-	-	-	-	-	-	-	-	-	-	-	-
Mean Lateral Ø (cm)	6.20	7.50	5.50	11.08	11.80	7.70	9.58	8.40	6.93	9.15	1.35	1.00
Vertical Canopy Height (m)	1.11	1.20	0.87	2.0	2.0	2.0	1.8	1.8	2.0	3.0	1.15	1.20
Mean Horizontal canopy Ø; CD, m)	3.4	3.05	3.4	4.1	5.1	3.8	4.1	5.4	4.4	5.1	1.1	1.05
LCR	0.41	0.46	0.25	0.50	0.44	0.40	0.36	0.36	0.50	0.60	0.82	0.83
Canopy Volume, CV (m^3)	9.1	6.0	2.0	17.8	27.8	14.7	15.7	28.5	21.3	40.9	0.75	0.75
Capsules (CP)	690	453	418	413	241	307	446	323	832	1606	6	42
Basal Area, BA (cm^2)	114.93	91.90	97.60	741.72	215.30	215.80	218.40	240.96	161.19	411.47	7.54	9.6
Complexity index (Ci)	29.47	13.12	18.14	2156.5	233.22	187.43	154.41	295.11	117.96	172.81	0.036	0.053
Canopy Shape	HSph	HSph	HSph	HSph	HSph	HSph	HSph	HSph	HSph	HSph	HSph	Sph

Ø, Locality- HB, HB1, Hawkes Bay sample1 & 2, HM, Hawkes Bay sample near Mosque, N1 – N5, North Nazimabad samples 1-5, CL, Clifton; B1-B7, Boat Basin samples 1-7; R1 – R5, Rimpa Plaza area samples 1-5 and K1-K3, Karsaz samples 1-3; GL, Gulshan-e- Iqbal. L_1 – L_6, Laterals (LB) from base to apex; Ø, Diameter; Sph, Spherical canopy; LCR, live crown ratio; HSph, Hemi-spherical canopy. *, Estimated stem diameter (cm) as per total basal area of the plant.

Table 3. Average morphometric characteristics for relatively younger (N =5) and mature (N = 20) *T. populnea* plants growing in saline environment in Karachi.

Parameter	Mean	SE	CV (%)	Mean	SE	CV (%)	Mean	SE	CV (%)
	Younger Plants (N=5)			Mature Plants (N=20)			All Plants (N=25)		
H	1.322	0.0462	7.81	4.112	0.1734	18.56	3.55	0.2664	37.56
LB	2.40	0.2449	22.82	3.00	0.2052	30.59	2.88	0.1763	30.60
LM	1.15	0.0592	11.50	8.434	0.1192	6.32	6.95	0.7391	53.18
CH	1.11	0.0292	5.87	2.082	0.1308	28.08	1.863	0.1315	35.28
LCR	0.798	0.0347	9.72	0.484	0.0386	35.68	0.578	0.0371	32.09
CD	1.022	0.02332	5.10	3.780	0.2396	28.34	3.23	0.2949	45.70
CV	0.720	0.04270	13.26	16.872	2.5796	68.37	13.64	2.4400	89.44
CP	12.0	7.58940	141.42	719.00	126.13	78.45	577.6	115.80	100.24
SD	2.80	0.21909	17.50	16.824	0.1685	4.48	14.04	1.672	59.53
Ci	0.0283	0.00759	59.86	260.63	47.71	81.87	207.36	43.424	104.70

The flowers and floral buds were not present on most of the trees at the time of observation or they were negligible in number with the exception of few plants (R1, R3, and R5) which bore substantial number of flowers and floral buds at the time of survey (Table 4). The number of capsules as counted on the sample trees in spring and autumn varied significantly within as well as among the trees. The highest number of capsules (2600 *in toto*) were counted in a plant (stem-size class C) of Boat Basin area (truly coastal locality) followed by a plant (representative to stem-size class D) of Karsaz area (1606 capsules *in toto*). The number of capsules in autumn on an average was 1.57 times of that of the spring. The autumn/ spring ratio of capsules did not vary significantly with the plant size of the reproducing trees ($F = 0.54$, $p < 0.781$) (Table 4; Fig. 1 and 2). The stem size class D corresponding to stem diameter 20-25cm, exhibited comparatively much higher variation in autumn: spring ratio of capsular production.

Key to the acronyms: H, height (m); LB, number of laterals; LM, mean lateral diameter, Canopy height; LCR, Live crown ratio; CD, Canopy diameter; CP, Number of capsules; SD, Stem diameter; BA, Basal area; CV, Canopy volume; and Ci, Complexity index (Units of the parameters as in Table 1).

i) Variation of number of seeds per capsule: The number of seeds produced in a capsule varied among the plants significantly ($F = 14.65$, $p < 0.001$). However, there was more variation at capsular level within a tree (67.57%) than among at the trees (32.43%). The mean number of seeds per capsule varied from 6.0 ± 0.389 in a Hawkes Bay sample of relatively premature plant to 15.2 ± 0.622 in a sample abounding with soil salinity of 7.7 $dS.m^{-1}$ in North Nazimabad – a mature plant of basal area around 846.6cm^2 and height 4.26m. Substantially lower number of seeds per capsule in Hawkes Bay samples presumably appears largely to be the function of their age - reproduction being a recent phenomenon in these plants. Indeed mean number of seeds per capsule appeared to be an age-related parameter as is evident from its positive correlation with Stem diameter (SD; $p < 0.05$) (Fig. 3). Mean number of seeds per capsule was somewhat less closely related with Basal area (BA; $r = 0.4044$, $p < 0.07$)).

The overall distribution pattern of seeds among capsules (Fig. 4) with overall mean of 11.8516 ± 0.17394 seeds per capsule and standard deviation of 4.2607 represented an asymmetrical population in which majority of cases concentrated in the region of 8 -18 seeds / capsule. The representation of cases larger than 18 seeds per capsule was substantially low in comparison to lower classes of, 2 to 6 seeds per capsule. The number of seeds per capsule related with stem diameter linearly significantly ($p < 0.05$) and the scatter delimited five classes – A, B, C, D and E corresponding to five SD classes (Fig. 3). Basal area also associated significantly with the number of seeds per capsules ($p < 0.05$) as given by the following equation:

$$\text{Seeds / Capsule} = 10.64591 + 0.004678 \text{ Basal Area } (cm^2) \pm 2.337$$

$t = 10.856 \quad t = 1.90$

$p < 0.001 \quad p < 0.07$

$R^2 = 0.1635$; $r = 0.4044$, $F = 3.52$, $p < 0.05$

Table 4. Number of floral buds, flowers and capsules present on *Thespesia populnea* trees on the dates of observation in spring and autumn.

Plant Location	Number of floral buds			Number of Flowers			Number of capsules		
	Spring	Autumn	Total	Spring	Autumn	Total	Spring	Autumn	Total
HB1	5	8	13	40	45	85	252	300	552
HM	-	-	-	-	5	5	28	50	78
HB	-	2	2	-	1	1	-	2	2
N1	4	0	4	0	0	0	180	200	380
N2	10	0	10	0	0	0	480	500	980
N3	5	0	5	0	0	0	350	368	718
N4	-	-	-	-	1	1	-	2	2
N5	3	2	5	3	4	7	2	6	8
CL	0	0	0	0	10	10	354	600	954
B1	0	0	0	0	0	0	1200	1400	2600
B2	3	0	3	17	0	17	430	493	923
B3	10	0	13	80	0	80	276	230	506
B4	0	0	0	0	0	0	560	400	960
B5	0	0	0	0	0	0	345	345	690
B6	0	1	1	0	0	0	216	237	453
B7	0	0	0	0	0	0	188	230	418
R1	22	0	22	160	15	185	140	273	413
R2	8	0	8	32	0	32	90	151	241
R3	15	0	15	75	0	75	110	197	307
R4	12	0	12	35	15	50	176	270	446
R5	18	0	18	135	0	135	110	213	323
K1	10	0	10	30	0	30	200	632	832
K2	30	0	30	60	0	60	400	1206	1606
K3	-	4	4	2	-	2	2	4	6
GL	6	-	6	5	1	6	16	26	42

*, Locality- HB1, Hawkes Bay sample1, HM, Hawkes Bay sample near Mosque, N1 – N5, North Nazimabad samples 1-5, CL, Clifton; B1-B7, Boat Basin samples 1-7; R1-R5, Rimpa Plaza samples 1-5 and K1-K3, Karsaz samples 1-3, GL, Gulshan-e-Iqbal.

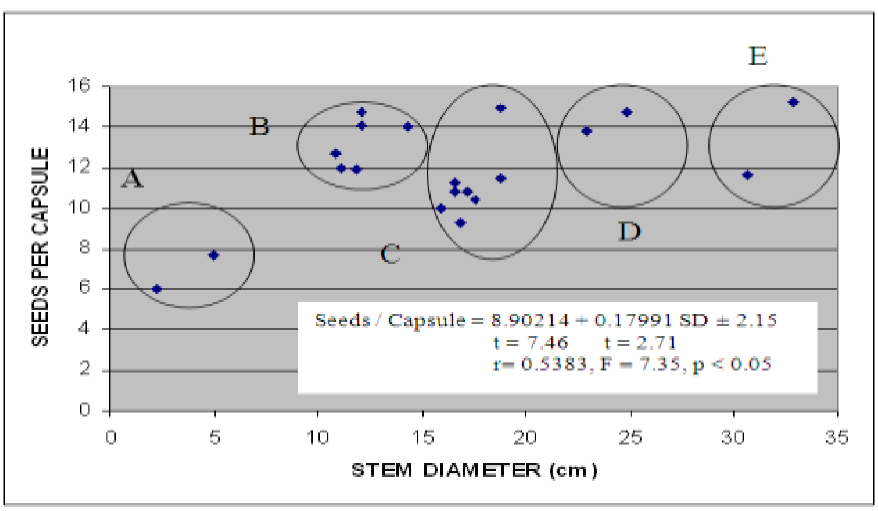


Fig. 3. Relationship of the mean number of seeds per capsule and stem diameter of *Thespesia populnea* trees. Note the discrete delimitation of scatter into five classes – A, B, C, D and E corresponding to five SD classes adopted for description.

iii) Variation of seed mass per capsule: Seed mass per capsule varied within and among plants significantly ($F = 20.43$) and average seed mass for a tree ranged from 0.989 ± 0.053 g in smaller plants to 2.31 ± 0.072 g per capsule in a moderately–sized tree of Boat-Basin area (B5). (Table 7 and 8).The seed mass per capsule varied slightly more within trees (59.28 %) than amongst trees (40.72%).

The overall average seed mass per capsule, based on observation of 585 capsules, was 1.604 ± 0.02426 g per capsule (range: 0.33 to 3.41 g) with variability around 36.6%. The distribution pattern of seed mass per capsule was non-skewed ($g_1 = 0.1046$) and mesokurtic. The distribution followed normal distribution pattern ($X^2 = 6.85$, $p < 0.2321$, NS) (Fig. 5).

There was a statistical relationship that plants with larger variability (Cvar) among seed weight classes within capsules were those with lower mean seed weight i.e., larger is the variation among seed weight classes within capsule, lower is the mean seed weight. This relationship was explicit from the following relationship.

Mean seed weight (mg) = 188.3435 – 2.58542 Cvar (%) ± 13.62
$t = 9.63$ $t = 2.73$
$p < 0.001$ $p < 0.014$
$r = 0.5409$, $F = 7.45$, $p < 0.05$

iv) Variation in mean seed weight for individual trees: The mean seed weight for a mean tree representative to a plant size class based on the size of stem varied from 120.35 mg for size class E (> 25 cm stem diameter) to 148.74 mg for size class B (10 – 15 cm stem diameter) (Fig. 6). The variation of seed weight among and within classes was, however, more or less equally explained (51.89 and 48.11%, respectively).

Average seed weight for individual *T. populnea* trees varied from 106.43 ± 1.41 mg to 168.11 ± 2.09 mg (Fig. 7) being presumably determined by the external and internal environment of the maternal plants. Ten plants showed mean seed weight lower than the grand mean and 9 trees showed mean seed weight to be higher than the grand mean (135.99 ± 0.3719 mg). There was slight tendency of mean seed weight to be negatively skewed among the trees. The distribution of seed weight for individual *Thespesia* trees was distributed unevenly around the grand mean value.

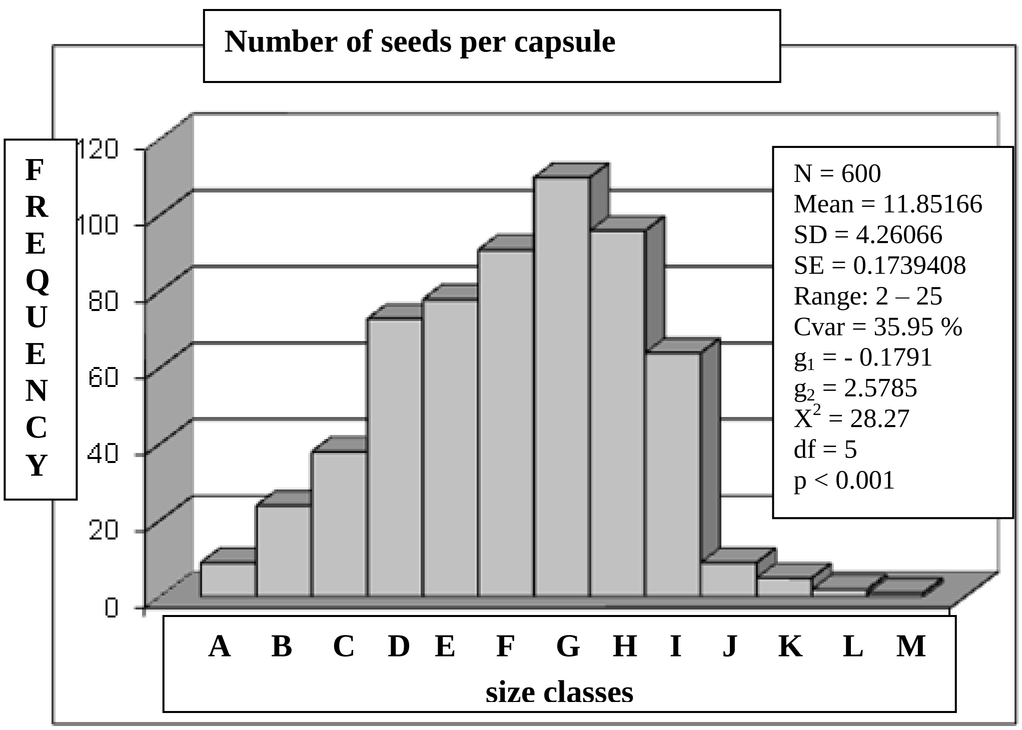
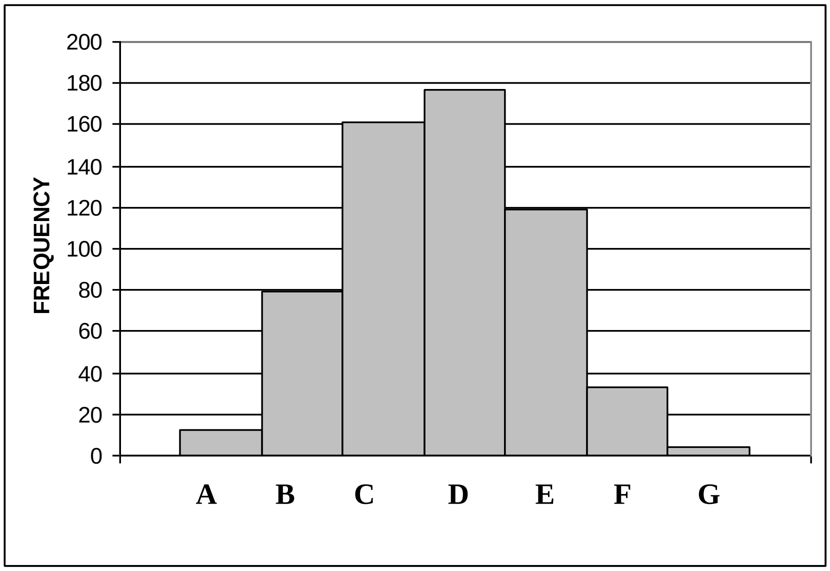


Fig.4. Frequency distribution of number of seeds per capsule in *Thespesia populnea* trees growing naturally under saline condition in Karachi. Size classes: A, < = 2; B, 3-4; C, 5-6, D, 7-8; E, 9-10 and M > = 25 seeds per capsules. The hypothesis that population is normal (of mean 11.85166 and SD 4.26066) can be rejected at 95% confidence level. g1 and g2 calculated as $g_1 = K_3/(K_2')^{3/2}$ and $g_2 = K_4/(K_2')^2$. Ks, the moments around mean.

$Sg1 = \sqrt{6N (N-1) / (N-2) (N+1)(N+3)} = 0.09240$ and

$Sg2 = \sqrt{24N (N-1)2 / (N-3) (N-2) (N+3) (N+5)} = 0.1992$

Variation in terms of coefficient of variation (Cvar %) among the seeds within any tree of *T. populnea* was generally less than or around 20% except little higher in case of younger plants (HM & N1) which most probably entered reproduction first time and came up with relatively low reproductive produce in terms of number of capsules (Table 5).



N= 585
Mean= 1.603795g
SE= 0.024259
Minimum= 0.33
Maximum = 3.41
Cvar = 36.55%
g_1= 0.104635
g_2= 2.554962
X^2= 6.85
P< 0.2321

Fig.5. Frequency distribution of seed weight per capsule of *Thespesia populnea*. The size classes: A, 0 – 0.5g; B, 0.51-1.0g; C, 1.01-1.5g; D, 1.51- 2.0; ….. G, 3.01-3.5g. The hypothesis that population with mean 1.603795 and Standard deviation of 0.587655 is normal cannot be rejected at 95% confidence level. g_1 and g_2 calculated as $g_1=K_3/(K_2')^{3/2}$ and $g_2 = K_4/(K_2')^2$. Ks, the moments around mean.

$Sg_1= \sqrt{6N (N-1) / (N-2) (N+1) (N+3)} = 0.0101$;

$Sg_2 = \sqrt{24N (N-1)2 / (N-3) (N-2) (N+3) (N=5)} = 0.2017$

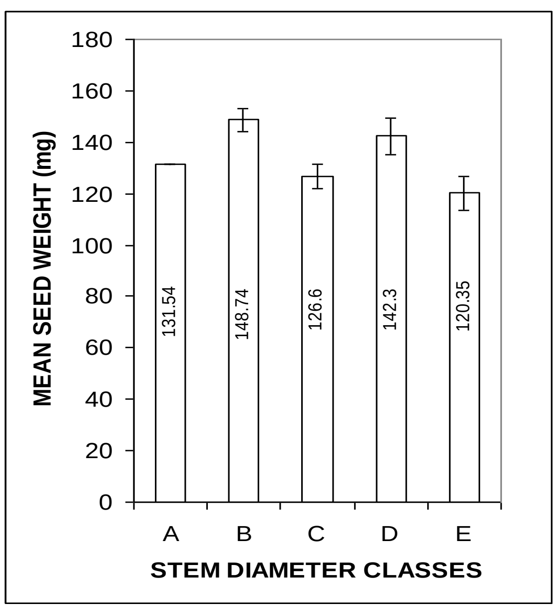


Fig.6. Mean seed weight (mg) of mature trees of *T. populnea* grouped in five size classes according to stem diameter. These trees were growing in differentially saline environment of Karachi. Stem diameter classes: A, < 10 cm; B, 10 – 15 cm; C, 15 – 20, cm; D, 20 – 25 cm; and E , > 25 cm. Class A consisted of plants with stem diameter ≤ 5 cm and producing relatively lesser number of capsules.

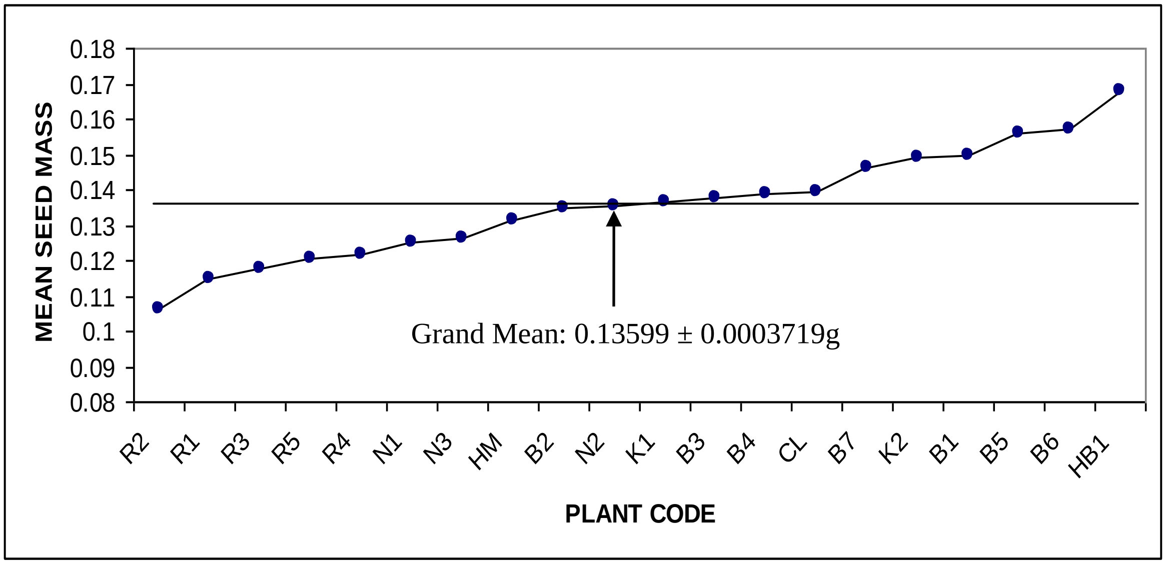


Fig.7. Variation in mean seed masses of *Thespesia populnea* individuals growing in saline coastal conditions of Karachi. The Standard errors being low are covered by the points. The straight line represents the grand mean of 0.13599 ± 0.0003719g. Minimum mean seed mass per seed for a tree was 0.10643 ± 0.00141g and maximum 0.16810 ± 0.00209g. The tendency of negative skewness in the data is explicit. Plant code as in Table 1.

v) Variation of individual seed weight: For each tree, 30 capsules (15 capsules in case of a Hawkes Bay sample, HM) were opened and in all 6933 seeds were recovered from 585 capsules. Distribution pattern of seed weight for the pooled lot of seeds (6899 in number) of all trees (discarding the seeds with ≤ 10 mg in mass from the analysis) is presented in Fig.8.

Table 5. Location and dispersion of seed weight (g) per capsule of *T. populnea* trees.

Plant Code	Mean seed wt. per capsule (g)	N	SE	Cv (%)	Maximum	Minimum	Max / Min Ratio
HB1	0.989	30	0.05295	29.92	1.52	0.36	4.22
HM	1.035	15	0.13126	49.14	1.54	0.33	4.66
B1	1.002	30	0.09214	31.43	1.97	0.51	3.86
B2	1.964	30	0.09239	25.18	2.70	0.95	2.84
B3	1.567	30	0.07262	24.72	2.65	0.86	3.08
B4	1.955	30	0.06495	18.29	2.48	0.60	4.13
B5	2.310	30	0.07238	18.55	2.68	0.40	6.7
B6	1.978	30	0.10241	28.28	2.92	1.12	2.60
B7	1.804	30	0.09242	28.06	2.52	0.87	2.90
CL	1.694	30	0.09183	29.68	2.69	1.32	2.04
N1	1.197	30	0.06263	28.30	3.41	1.32	2.58
N2	1.911	30	0.07980	25.21	3.41	0.85	4.01
N3	1.814	30	0.08011	24.18	2.74	0.60	4.60
R1	1.256	30	0.06838	29.58	1.74	0.62	2.81
R2	1.222	30	0.08254	38.09	2.15	0.36	5.97
R3	1.195	30	0.07828	35.94	2.15	0.40	5.38
R4	1.133	30	0.06599	31.89	2.04	0.57	3.58
R5	1.269	30	0.07950	34.30	2.25	0.49	4.59
K1	1.837	30	0.09129	27.21	2.75	0.51	5.40
K2	1.950	30	0.09585	26.63	2.82	1.76	1.60
Grand Mean of seed weight per capsule = 1.604 ± 00243; N = 585							

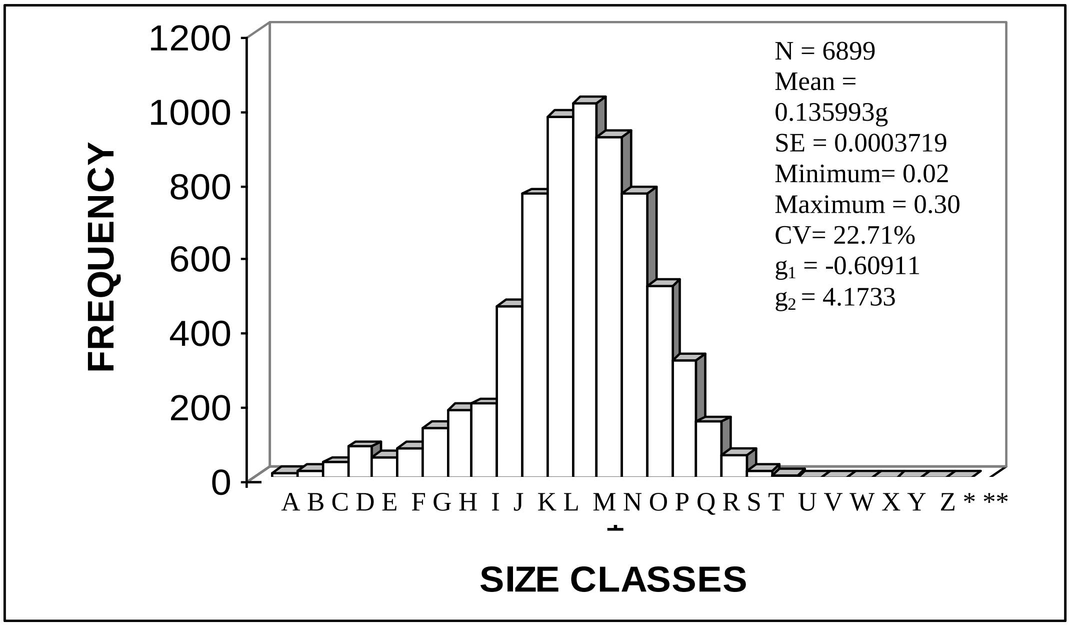


Fig.8. Frequency distribution of seed weights of *Thespesia populnea* (pooled for 20 trees). Size classes: A, 0.02-0.03g: B, 0.03-0.04; C, 0.04-0.5; D, 0.05-0.06; E, 0.06-0.07; F, 0.07 – 0.08; G, 0.08-0.09…..Q, 0.18-0.19………..Y, 0.26-0.27; Z, 27-0.28; *, 0.28-0.29and **, 0.29-0.30. The classes Y, * and ** were represented by one seed each and classes V, W and X had no representative seed. The population was leptokurtic and negatively skewed.

g_1 and g_2 calculated as $g_1 = K_3/(K_2')^{3/2}$ and $g_2 = K_4/(K_2')^2$; Ks, the moments around mean.
$Sg_1 = \sqrt{6N (N-1) / (N-2) (N+1) (N+3)} = 0.029486$
$Sg_2 = \sqrt{24N (N-1)^2 / (N-3) (N-2) (N+3) (N+5)} = 0.05895$

The mean seed weight was found to be 135.99 ± 0.3719 mg with coefficient of variation among the seed weights, 22.71%. The individual seed weight in *T. populnea* ranged from 20 to 300 mg – a 15 folds variation. The variance components analysis showed that approximately 79.29% of the total variation in seed mass was within trees and 20.73% between the trees ($F= 94.63$, $p < 0.0001$). The seed weight distribution was leptokurtic and negatively skewed.

Seed crop: The estimated fecundity of the plants in terms of number of seeds and seed yield per plant is presented in Table 6. The fecundity varied greatly from plant to plant (16 – 29822). The younger plants produced very low number of seeds than that of mature plants. Amongst the mature plants largest seed crop was in B1 plant (size class C) of Boat Basin area (SN = 29822 seeds, SY= 4.47 kg) followed by a plant (size class D) of Karsaz area (SN = 221632, SY = 3.31 kg) corresponding with the larger number of capsules produced by these plants. Average number of seeds per mature plant was 8896.5 ± 1604.3 with coefficient of variability 80.65%. Average SY per mature plant was 1.25 ± 0.2169 kg – varying around 86.4%. It may be noted that this variation in number of seeds produced by *T. populnea* trees was much higher than the variability exhibited by the seed weights of these plants on individual seed basis which amounted 22.7% (Fig. 8) only.

The average number of capsules, seeds and seed mass produced in a year in five groups of variously sized trees of *Thespesia* are depicted in Fig. 9. Trees of size class D (20-25 cm stem diameter) were the most productive. The average number of capsules, seeds and seed yield per plant gradually increased along the plant size and were maximum in plants of 20 – 25 cm stem diameter. These parameters, however, declined in larger plants of more than 25 cm stem diameter. Variation in these parameters was accounted for more within the size classes (56.34 – 61.26%) than among the classes (38.74 – 43.66%).

Table 6. Estimated number of seeds per tree and seed yield (Kg / tree) of *Thespesia populnea* trees growing under saline conditions in Karachi.

S. No.	Tree	Number of Seeds / Plant	Seed Yield (Kg / Plant)
1.	HM*	601	0.08
2.	HB1	3312	0.56
3.	HB	12	0.002 (Minimum)
4.	N1	3686	0.46
5.	N2	14376	1.95
6.	N3	10914	1.37
7.	N4	16	0.002
8.	N5	67	0.009
9.	CL	11190	1.56
10.	B1	29822	4.47 (Maximum)
11.	B2	9968	1.34
12.	B3	7554	1.04
13.	B4	13469	1.87
145	B5	10164	1.59
15.	B6	5753	0.90
16.	B7	5004	0.73
17.	R1	4791	0.55
18.	R2	2716	0.29
19.	R3	3325	0.39
20.	R4	4117	0.53
21.	R5	3359	0.41
22.	K1	11648	1.59
23.	K2	22163	3.31
24.	K3	43	0.006
25.	GL	336	0.044

Location & Dispersion parameters for number of seeds and seed yield excluding smaller sample plants viz. HB, N4, N5, K3, and GL.

Mean	8896.5	1.2495
SE	1604.3	0.24125
Range	601 – 29822	0.08 – 4.47
Cvar	80.65 %	86.35 %
N	20	20

*, Locality- HB1 & HB, Hawkes Bay sample1 & 2; HM, Hawkes Bay sample near Mosque, N1 – N5, North Nazimabad samples 1-5, CL, Clifton; B1-B7, Boat Basin samples 1-7; R1-R5, Rimpa Plaza area samples 1-5 and K1-K3, Karsaz samples 1-3; GL, Gulshan-e-Iqbal sample.

Multi-colinearity among vegetative - morphometric and reproductive parameters: Relationship among various vegetative and reproductive parameters of plant studies through linear correlation analysis, all plants inclusive (N = 25), is presented in Table 7. There was a substantial degree of Multi-colinearity among the morphometric parameters. Untransformed data generally yielded low values of r which were greatly improved on $\log_e$ transformation of the X ant Y variables. By virtue of this analysis height (H) of the *Thespesia* plants best related with Stem diameter (SD), Basal area (BA), Canopy volume (C_{vol}) and mean lateral branch diameter LM but comparatively poorly with reproductive variables. SD was very closely related with BA and moderately with (LM) and other variables. Number of main lateral branches yielded poor relationship.

Live Crown ratio (LCR) correlated significantly negatively with H (r = -0.6940), SD (r = -0.5723), CD (-0.7282) and mean diameter of laterals, LM (r = -0.6268) i.e., LCR progressively declined with tree maturity. The estimated number of seeds per plant (SN) and total seed yield per plant (SY) related closely with number of capsules per plant (CP) but somewhat less closely with height (H). SN related positively significantly with BA. SY exhibited best fit relationship with BA and LM which itself correlated with BA very closely (r = 0.9424). The relationship of SN and SY with SD, BA, and LM were of general predictive value. However, among the three vegetative variables BA appeared to be more appropriate, particularly in case of SN.

Allometric Equations: The allometric equations derived from simple linear and multiple linear regressions for logarithmically transformed data (Log_e) for fecundity (reproductive dependent variables such number of capsules per plant (lnCP), number of seeds per plant (lnSN) and seed yield (Kg) per plant (lnSY)) of *T. populnea* and its vegetative morphometric parameters as independent variables such as Height (lnH), Canopy diameter (lnCD), Canopy volume (lnCvol), Stem diameter (lnSD) and Basal area (lnBA) are presented in Table 8 . The independent parameters in their singular capacity although yielded statistically significant power equations with number of capsules per plant but they couldn't define more than 79.2 % of the total variation in data (Table 8; equations 1-5). The linear combinations of lnH with lnSD and lnCD with lnBA improved the relationship to account for around 83% of the variation in lnCP (Table 8; equation # 6 and 8).

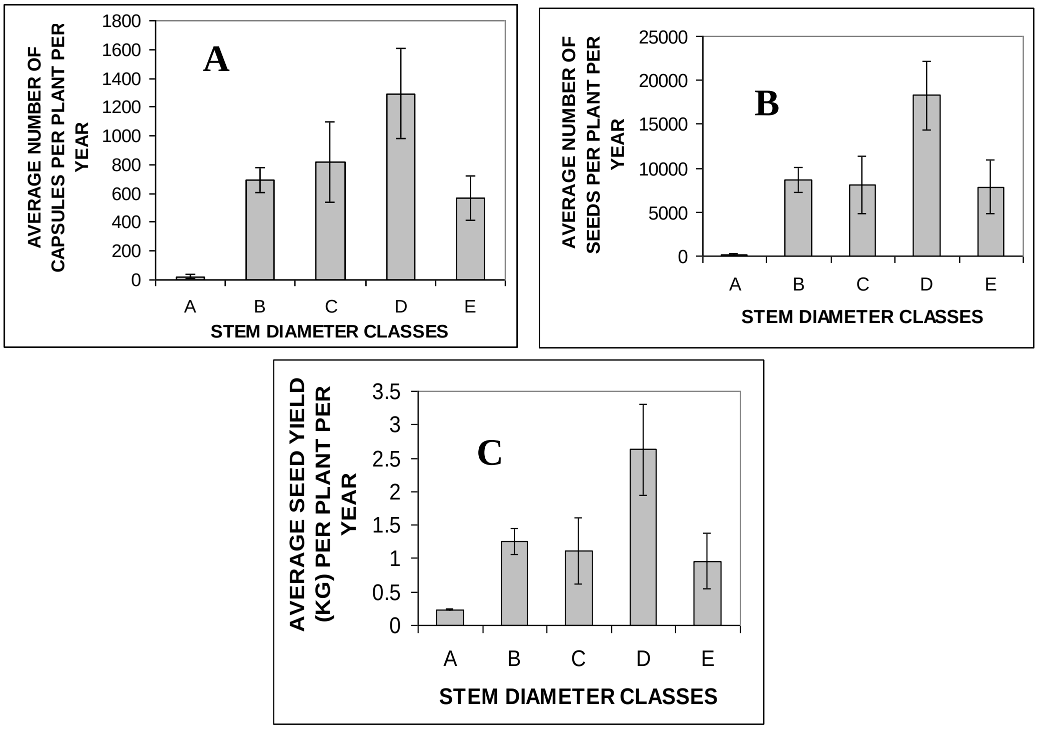


Fig. 9. Average number of capsules (A) and seeds (B) (plant $^{-1}$.year $^{-1}$) and seed yield (C) (kg.plant $^{-1}$.year $^{-1}$) in trees of *T. populnea* as influenced by the tree size represented by the stem diameter (SD). Key to the stem diameter classes: A < 10 cm; B, 10 – 15 cm; C, 15 – 20 cm; D, 20 - 25cm and E, > 25cm.

Similar results as given above were obtained with number of seeds per plant (lnSN) when regressed singularly with lnH, lnCD, lnCvol or lnBA (Eq. 9 – 12). lnBA, however, explained around 81% of the variation in lnSN (Eq. 13). Linear combination of lnCD with lnBA also couldn't explain more than 80.8% variation in lnSN (equation # 15). Seed yield (lnSY, kg / plant) behaved in similar fashion as the above dependent variables. None of the equations of simple or multiple regression analysis could explain more than 77.9% variation in lnSY (Table 8; equation # 16 -24).

The number of capsules per plant (lnCP) and estimated number of seeds per plant (lnSN) were found to be statistically ($p < 0.001$) best related with lnBA in curvilinear fashion. These quadratic power equations (Table 9; equations # 5 and 10) were not only statistically significant ($p < 0.001$) in respect of r, t, and F, also had high explanatory power to account for variation (around 91%) in number of capsules and seeds per plant. LnSN also related with LnSD equally closely with explanatory capacity around 91.4% (Eq. 9, Table 9).These equations are valuable in predicting CP and SN in *T. populnea* on the basis of basal area of the plant under the given environmental conditions. It may, however, be mentioned here that present analysis is based on fecundity data for one year only. For more reliable relationships, observations on fecundity of *T. populnea* for several years may be necessary for more general application.

The quadratic predictive equations for lnSY with lnH, lnCD, lnCV and lnBA although were statistically significant but had somewhat low explanatory power (less than 84%) to define variation in lnSY (Table 9).

ln CP, ln SN and ln SY related significantly in curvilinear fashion with the complexity index (ln Ci) derived following the practice of Pool *et al.* (1977) and gave following predictive equations but with somewhat lower explanatory powers (81.4, 81.6 and 76.6%, respectively). Compared to the complexity index, therefore, stem diameter was a better morphometric parameter relating to the reproductive potential of the plant.

Table 7. Pearson Product Moment Correlation coefficients among morphometric attributes and reproductive yield of *Thespesia populnea* trees growing under saline conditions in Karachi.

H	H									
SD	a) 0.7619 b) 0.9188	SD								
LB	0.2864 0.3099	0.3729 0.4152	LB							
BA	0.5604 0.9185	0.9493 0.9999	0.3288 0.4159	BA						
CD	0.8189 0.9138	0.6031 0.8489	0.4780 0.4232	0.3783 0.8488	CD					
CV	0.7010 0.9138	0.4953 0.8491	0.5340 0.3966	0.3277 0.8490	0.8856 0.9521	CV				
CP	0.5736 0.8940	0.4826 0.8918	0.3223 0.4419	0.3504 0.8917	0.4171 0.8495	0.4125 0.8403	CP			
SN	0.5366 0.8760	0.5213 0.9008	0.3365 0.4657	0.4038 0.9008	0.4299 0.8522	0.4062 0.8343	0.9814 0.9961	SN		
SY	0.4845 0.8386	0.4602 0.8541	0.3139 0.4616	0.3476 0.8540	0.3948 0.8423	0.3764 0.8080	0.9680 0.9612	0.3476 0.8540	SY	
LM	0.8080 0.9307	0.8882 0.9425	0.1970 0.2553	0.7668 0.9424	0.6888 0.8826	0.4881 0.8649	0.4267 0.8701	0.4605 0.8736	0.4197 0.8669	LM

a, Untransformed data b, Double loge transformed data. *, H, Height (m): BA, Basal area (cm^2); LB, Number of major laterals; CD, Canopy diameter (m); CV, Canopy volume (m^3): CP, number of capsules per plant; SN, Estimated number of seeds per plant; SY, Seed yield (Kg/plant); LM, Mean diameter of laterals. N = 25; df; 23; $r_{p<0.05}$, 0.3980; $r_{p<0.01}$, 0.5070; $r_{p<0.001}$, 0.6190.

Table 8. Some good-fit linear predictive equations for number of capsules / plant (ln CP), number of seeds per plant (lnSN) and seed yield per plant (ln SY) in relation to the morphometric parameters of *Thespesia populnea*.

Number of capsules per plant (ln CP)

ln CP = 1.1063 + 3.6935 ln H ± 1.14; R^2 = 0.7993; Adj. R^2 = 0.7906; F = 91.61 t = 2.27 t = 9.71 p < 0.03 p < 0.001	EQ. # 1
ln CP = 2.3143 + 2.9665 ln CD ± 1.09; R^2 = 0.7215; Adj R^2 = 0.7094; F = 59.60 t = 5.05 t = 7.72 p < 0.001 p < 0.001	EQ. # 2
ln CP = 2.9850 + 1.2338 ln CV± 1.12; R^2 = 0.7061; Adj R^2 = 0.6933; F = 55.27 t = 7.50 t = 7.43 p < 0.001 p < 0.001	EQ. # 3
ln CP = 0.01301 + 2.25589 ln SD ± 0.9394; R^2 = 0.7953, Adj. R^2 = 0.787, F = 89.41 t = 0.02 t = 9.46 P < 0.98 p < 0. 001	EQ. # 4
ln CP = 0.28389 + 1.12858 ln BA ± 0.9388; R^2 = 0.7952, Adj. R^2 = 0.7863, F = 89.32 t = 0.49 t = 9.45 P < 0.62 p < 0. 001	EQ. # 5
ln CP = 0.3699 + 1.9784 ln H + 1.1429 ln SD ± 0.8718; R^2 = 0.8311; Adj. R^2 = 0.816; F = 54.13 t = 0-.64 t = 2.16 t = 2.04 p< 0.64 p < 0.04 p < 0.05	EQ. # 6
ln CP = 2.0403 + 0.88268 CD + 0.002418 BA ± 1.33; R^2 = 0.603; Adj r^2 = 0.5667; F = 16.7 T = 3.08 t = 4.42 t = 1.78 P < 0.005 P < 0.001 p < 0.089	EQ. # 7
ln CP = 0.691513 + 1.15600 ln CD + 0.77299 ln BA ± 0.8853 T = 1.19 t = 1.97 t = 3.63 P < 0.24 p < 0.062 p < 0.001 R^2 = 0.8258; Adj R^2 = 0.8100; F = 52.17	EQ. # 8

Number of seeds per plant (ln SN)

ln SN = 3.09806 + 4.0078 ln H ± 1.09; R^2 = 0.7726; Adj. R^2 = 0.7628; F = 78.13 t = 5.41 t = 8.84 p < 0.001 p < 0.001	EQ. # 9
ln SN = 1.7515 + 2.5146 ln SD ± 0.9943; R^2 = 0.8114; Adj.R^2 = 0.8032; F =98.83 t = 2.74 t = 9.95 P < 0.012 p< 0.001	EQ. # 10
ln SN = 4.3401 + 3.28441 ln CD ± 1.19; R^2 = 0.7262; Adj. R^2 = 0.7143; F = 61.01 t = 8.64 t = 7.81 p < 0.012 p < 0.001	EQ. # 11
ln SN = 5.1107 + 1.35186 ln CV± 1.26; R^2 = 0.6961; Adj. R^2 = 0.6828; F = 52.67 t = 11.44 t = 7.26 p < 0.001 p < 0.001	EQ. # 12
ln SN = 2.05311 + 1.258103 ln BA ± 0.9944; R^2 = 0.8113; Adj. R^2 = 0.8031; F = 98.93 t = 3.37 t = 1.95 p < 0.001 p < 0.001	EQ. # 13
lnSN =4.01232 + 0.96919CD + 0.002923BA ± 1.43; R^2 = 0.623; Adj. R^2 = 0.589; F = 18.2 t = 5.64 t = 4.51 t = 2.00 p < 0.001 p < 0.001 p < 0.058	EQ. # 14
ln SN = 2.47913 + 1.20814 ln CD + 0.88648 ln BA ± 0.9398 t = 4.02 t = 1.94 t = 3.92 p < 0.001 p < 0.06 p = 0.001; R^2 = 0.8088; Adj. R^2 = 0.8042; F = 57.26	EQ. # 15

Table 8. Continued

Seed yield per plant in kg (ln SY)

ln SY = -5.5931 + 3.82638 ln H ± 1.24 R^2 = 0.7294; adj. R^2 = 0.7176; F = 62.00 t = -8.53 t = 7.38 P < 0.001 p < 0.001	EQ. # 16
ln SY = -5.5931 + 3.82638 ln H ± 1.24 R^2 = 0.7294; adj. R^2 = 0.7176; F = 62.00 t = -8.53 t = 7.38 P < 0.001 p < 0.001	EQ. # 17
ln SY = -4.526 + 3.2487 ln CD ± 1.23 R^2 = 0.7094; R^2 = 0.6968; F = 56.16 t = -8.75 t = 7.49 p < 0.001 p < 0.001	EQ. # 18
ln SY = - 3.71023 + 1.310262 ln CV ± 1.35 R^2 = 6529; Adj. R^2 = 0.6324; F = 43.26 t = -7.77 t = 6.58 p < 0.001 p , 0.001	EQ. #19
Ln SY = - 6.55707 + 1.19387 ln BA ± 1.19 R^2 = 0.7294; Adj. R^2 = 0.7176; F = 61.99 t = - 8.98 t = 7.87 P < 0.001 p < 0.001	EQ. # 20
ln SY = -4. 82653 + 0.96725 CD + 0.002634 BA ± 1.496 t = - 6.51 t = 4.32 t = 1.73 p < 0.001 p < 0.001 p < 0.064 R^2 = 0.5919; Adj R^2 = 0.5547; F = 15.95	EQ.# 21
ln SY = - 5.98605 + 1.619349 ln CD + 0.69566 ln BA ± 1.102 t = -8.28 t = 2.21 t = 2.62 p < 0.001 p < 0.03 p = 0.016 R^2 = 0.7585; Adj. R^2 = 0.779; F = 38.70	EQ. # 22
ln SY = -5.05765 + 0.104501 SD + 0.75646 CD ± 1.42 t= - 7.09 t = 2.41 t = 3.07 p < 0.001 p < 0.025 p < 0.006 R^2 = 0.6328; Adj. R^2 = 0.5996; F = 18.95	EQ. # 23
ln SY = -6.15274 + 1.618831 ln CD + 1.39065 ln SD ± 1.102 t = - 7.96 t = 2.21 t = 2.62 p < 0.001 p < 0.038 p < 0.016 R^2 = 0.7786; Adj. R^2 = 0.7585; F = 38.70	EQ. # 24

Table 9. Curvilinear relationship of number of capsules per plant (ln CP), estimated number of seeds per plant (ln SN) and seed yield (ln SY) of *Thespesia populnea* with morphometric parameters like height, basal area and crown diameter and volume. ($Y = a + bX + CX^2 \pm SE$)

Capsules per plant (CP)

ln CP = - 0.65290 + 9.6964 ln H – 3.28898 $(\ln H)^2$ ± 0.7541 t = 1.04 t = 5.71 t = -3.60 p < 0.31 p < 0.001 p < 0.002; R^2 = 0.8736; Adj. R^2 = 0.8622; F = 76.05	EQ. # 1
ln Cp = 1.65463 + 7.16447 ln CD – 2.6275 $(\ln CD)^2$ ± 0.8274 t = 4.37 t = 6.99 t = - 4.27 p < 0.001 p < 0.001 p < 0.001; R^2 = 0.8479; Adj. R^2 = 0.8340; F = 61.31	EQ. # 2
ln CP = 2.9491 + 2.5413 ln CV – 0.443616 $(\ln CV)^2$ ± 0.8664 t = 9.51 t = 7.21 t = 3.99 p < 0.001 p < 0.001 p < 0.001; R^2 = 0.8293; Adj. R^2 = 0.8138; F = 53.45	EQ. # 3
ln Cp = -4.4900 + 7.48300 ln SD – 0.31534 $(\ln SD)^2$ ± 0.6221 t = -4.94 t = 7.21 t = - 3.99 p < 0.001 p < 0.001 p < 0.001; R^2 = 0.8293; Adj. R^2 = 0.8138; F = 53.45	EQ. # 4
ln Cp = -3.61457 + 3.59201 ln BA – 0.31534 $(\ln BA)^2$ ± 0.6225 t = -4.49 t = 7.91 t = - 5.51 p < 0.001 p < 0.001 p < 0.001; R^2 = 0.9139; Adj. R^2 = 0.9061; F = 116.74	EQ. # 5

Table 9. Continued

]estimated number of seeds (SN)

ln SN = 1.03942 + 11.0365 ln H – 3.8489 $(\ln H)^2$ ± 0.8877 t = 1.40 t = 5.52 t = - 3.58 P < 0.17 p < 0.001 p < 0.002 R^2 = 0.8562; Adj. R^2 = 0.8432; F = 65.52	EQ. # 6
ln SN = 3.6469 +7.69633 ln CD – 2.7614 $(\ln CD)^2$ ± 0.9342 t = 8.51 t = 6.65 t = - 3.98 P < 0.001 p < 0.001 p < 0.001; R^2 = 0.8408; Adj. R^2 = 0.8263; F = 58.08	EQ. # 7
ln SN = 5.071548 + 2.78155 ln CV – 0.48505 $(\ln CV)^2$ ± 1.00 t = 14.31 t = 6.90 t = - 3.81 P < 0.001 p < 0.001 p < 0.001; R^2 = 0.8168; Adj. R^2 =0.8004; F = 49.11	EQ. # 8
ln SN = -2.79171 + 3.78597 ln SD– 0.1.2763 $(\ln SD)^2$ ± 0.7008 t = - 2.72 t = 7.18 t = - 4.93 p < o.oo1 p < 0.oo1 p < 0.001; R^2 = 0.9104; Adj. R^2 = 0.9021; F = 111.78	EQ. # 9
ln SN = -1.8753 + 3.740479 ln BA – 0.31776 $(\ln BA)^2$ ± 0.7012 t = - 2.07 t = 7.31 t = - 4.93 p < 0.001 p < 0.001 p < 0.001; R^2 = 0.9103; Adj. R^2 = 0.9021; F = 111.63	EQ. # 10

Estimated yield of seeds (ln SY)

ln SY= -8.1982 + 12.5159 ln H – 4.8706 $(\ln H)^2$ ± 0.9464 t = -10.38 t = 5.96 t = - 4.29 P < 0.001 p < 0.001 p < 0.001; R^2 = 0.8369; Adj. R^2 = 0.8280; F = 56.62	EQ. # 11
ln SY = -5.2421 +7.8081 ln CD – 2.8838 $(\ln CD)^2$ ± 0.9616 t = -11.89 t = 6.56 t = - 3.99 P < 0.001 p < 0.001; p < 0.001; R^2 = 0.8316; Adj. R^2 = 0.8163; F = 54.31	EQ. # 12
ln SY= -3.7519 + 2.8378 ln CV – 0.5162 $(\ln CV)^2$ ± 1.075 t = -9.86 t = 6.55 t = - 3.75 p < 0.001 p < 0.001 p < 0.001; R^2 = 0.7896; Adj. R^2 =0.7706; F = 41.29	EQ. # 13
ln SY = 12.31865 + 8.5693 ln SD – 1.43922 $(\ln SD)^2$ ± 0.1.0179 t = - 8.27 t = 5.44 t = - 3.84 p < 0.001 p < 0.001 p < 0.0.001; R^2 = 0.8404; Adj. R^2 = 0.8258; F = 57.95	EQ. # 14
ln SY = -10.5215 + 3.6988 ln BA – 0.3207 $(\ln BA)^2$ ± 0.0.9661 t = - 7.43 t = 5.27 t = - 3.61 p < 0.012 p < 0.001 p < 0.001; R^2 = 0.8299; Adj. R^2 = 0.8145; F = 53.70	EQ. # 15

ln CP = 3.8988 + 0.048703 ln Complexity index ± 0.8945
t = 16.6 t = 10.0
p < 0.001 p < 0.001
R^2 = 0.8141; Adj. R^2 = 0.8060; F = 100.89
ln SN = 6.0972 + 0.53848 ln Complexity index± 0.980
t = 23.6 t = 10.1
p < 0.001 p < 0.001
R^2=0.8167; Adj. R^2 = 0.8088; F = 102.49

ln SY = -2.7568 + 0.52266 ln Complexity index± 1.102
t = -9.53 t = 8.74
p < 0.001 p , 0.001
R^2 = 0.7676; Adj. R^2 = 0.7585; F = 76.39

Salinity relations of number of seeds and seed yield per capsule: Average ECe of the soil and number of the seeds per capsule appeared to bear no correlation at all. The scatter diagram between these two variables although seems to reflect a curvilinear relationship between them, it appears not to be the case with the data in hand. Samples

HB and HM of Hawkes Bay area, being smaller individuals entering reproduction first time but occurring in widely varying soil salinity, may definitely be considered as outliers in view of the halophytic nature of the plant (Fig. 10). The scatter diagram sans HM and HB1 indicates no relationship between the two parameters (r = 0.3612). High salinity may, of course, affect the process of seed-setting or other related process (s) of fruit and seed development in several plants.

The average seed yield (g) per capsule of mature plants (N = 20), however, exhibited a curvilinear relationship with soil salinity (ECe; $dS.m^{-1}$), the plants were found to associate with which at the time of observation. ECe, this way, explained around 42% variation in the seed mass per capsule of *Thespesia* trees. The optimum level of ECe, in accordance with the following relationship appeared to be around 32 $dS.m^{-1}$.

Mean seed yield (g) per capsule = 1.06773 + 0.051785 ECe – 0.000804 $(EC_e)^2$ ± 0.3145
t = 6.01 t = 3.46 t = - 3.44
$p < 0.0001$ $p < 0.003$ $p < 0.003$
R^2 =0.4178, F = 6.10.

Since SN and SY were the function of structural parameters of the plants as well as salinity, in order to have parameters independent of age, these parameters were expressed relative to the plant height as SN/H, SY/H and oil yield / H and related to the soil salinity associated with these plants at the time of observation. In all cases significant curvilinear relationship was observed. Salinity (ECe: $dS.m^{-1}$) explained around 22% of the variation in SN /H, and 23.3% in SY/H. (Fig. 11).

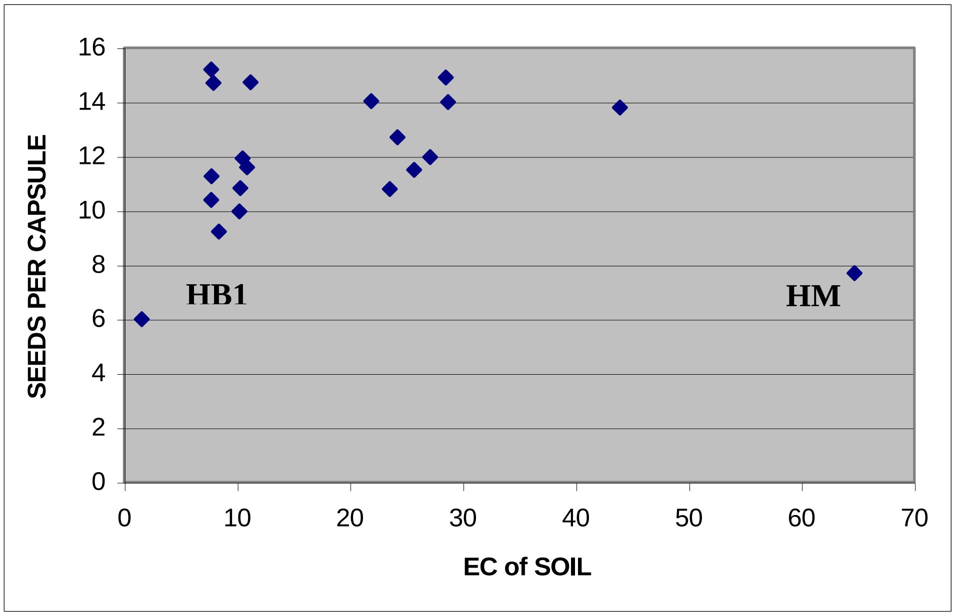
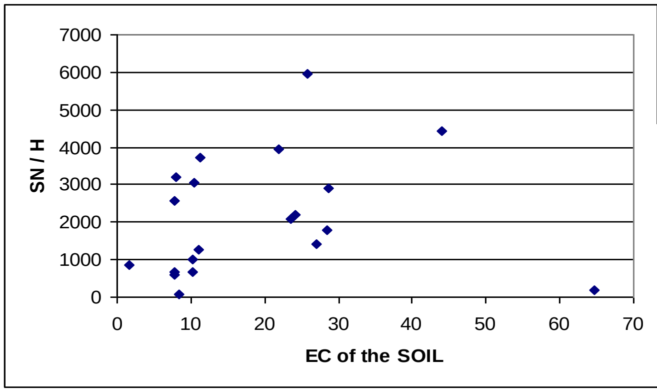


Fig. 10. Relationship between mean number of seeds per capsule and salinity (ECe: $dS.m^{-1}$) of the soil.

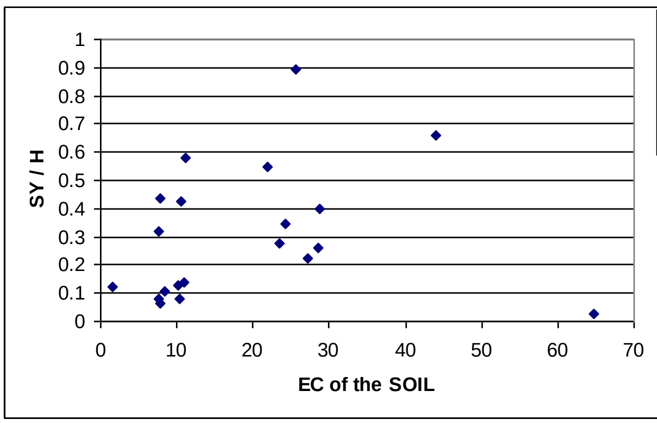
DISCUSSION

Thespesia populnea is cultivated in Karachi as an ornamental tree. Many of such plants were raised in sandy to clay-loam type of differentially saline soils of basic reaction or with saline water irrigation at least in early life. The plants studied were mostly below 5m in height. The younger plants around 1m or so had spherical canopy and mature trees were hemi-spherical in crown, generally monostemmic and rarely distemmic. The surface salinity ranged from 2.22$dS.m^{-1}$ to 166.7$dS.m^{-1}$ – generally higher on the surface presumably due to evaporation from surface of the soil. The highest salinity was encountered with a sample situated in salt marsh at Hawkes Bay. This plant, however, also received fresh water drained out from a nearby mosque. Plants of Karsaz area associated relatively with higher salinity level (28.7 – 43.93 $dS.m^{-1}$) than plants of Boat Basin area (11.20 – 28.5 $dS.m^{-1}$) or Plants of North Nazimabad (7.7 – 10.20 $dS.m^{-1}$). Na ion predominated in all the soil samples. Plants little higher than 1m in height with stem diameter around 2-3 cm were largely non-reproductive.

The number of capsules as counted on the sample trees at spring and autumn dates varied significantly within as well as among the trees. The highest number of capsules (2600 *in toto*) was counted in a plant (stem-size class of 15-20 cm) of Boat Basin area (truly coastal locality) followed by a plant (representative to stem-size class of 20-25 cm) of Karsaz area (1606 capsules *in toto*). The number of capsules in autumn on an average was 1.57 times of that of the spring. The autumn: spring ratio of capsules, however, did not vary significantly with the plant size of the reproducing trees. The stem size class D corresponding to stem diameter 20-25cm, exhibited comparatively much higher variation in autumn: spring ratio of capsular production. The reproductive variation in *T. populnea* plants as observed in this study could be a function of myriad of factors including salinity and moisture availability in root zone during flowering and fruiting and age of the plant. Each plant should have its own ecological history and reproductive success should be determined by several extrinsic and intrinsic factors interacting in complex fashion. The difference in form and architecture of branches may also affect resource partitioning, which in turn, may affect the reproductive capacity of a plant (Lechowicz, 1984).



$SN/H = 261.2878 + 180.5698\ EC - 2.71413(EC)^2 \pm 1395.3$
t = 0.33 t = 2.32 ($p < 0.015$ t = 2.61
$p < 0.74$ $p < 0.015$ $p < 0.018$
$R^2 = 0.3031$, Adj. $R^2 = 0.2212$, F= 3.70



$SN/H = 0.023495 + 0.027084\ EC - 0.000403\ (EC)^2 \pm 0.2039$
t = 0.204 t = 2.79 ($p < 0.015$ t 2.66
$p < 0.84$ $p < 0.013$ $p < 0.017$
$R^2 = 0.3139$, Adj. $R^2 = 0.2331$, F= 3.89

Fig.11.Relationship of number of seeds, seed yield (kg) expressed per plant per unit of height with EC ($dS.m^{-1}$) of the soil.

The number of seeds produced in a capsule varied among the plants significantly and average to 11.85±0.174. However, there was more variation at capsular level within a tree than among the tree. The mean number of seeds per capsule varied from 6.0 ± 0.389 in a Hawkes Bay sample of relatively premature plant to 15.2 ± 0.622 in a sample abounding with soil salinity of 7.7 $dS.m^{-1}$ in North Nazimabad – a mature plant of basal area around $846.6cm^2$ and height 4.26m. Substantially lower number of seeds per capsule in Hawkes Bay samples presumably appears largely to be the function of their age - reproduction being a recent phenomenon in these plants. Indeed mean number of seeds per capsule appeared to be an age-related parameter as is evident from its positive correlation with Stem diameter. The distribution pattern of seeds among capsules was asymmetrical in which majority of cases concentrated in the region of 8 -18 seeds / capsule. The representation of cases larger than 18 seeds per capsule was substantially low in comparison to lower classes of, 2 to 6 seeds per capsule. Our data is not in agreement with the average number of seeds per fruit (5-7 seeds) as reported by Parotta (1994).

Seed mass per capsule varied within and among plants significantly (F = 20.43) and average seed mass for a tree ranged from 0.989 ± 0.053 g in smaller plants to 2.31 ± 0.072 g per capsule in a moderately–sized tree). The seed mass per capsule varied slightly more within trees (59.28 %) than amongst trees (40.72%). The overall average seed mass per capsule was 1.604 ± 0.02426 g per capsule (range: 0.33 to 3.41 g) with variability around 36.6%. The distribution pattern was non-skewed and mesokurtic. The distribution followed normal distribution pattern.

Average seed weight for a tree varied from 106.43 ± 1.41 mg to 168.11 ± 2.09 mg being presumably determined by the external and internal environment of the maternal plants. Ten plants showed mean seed weight lower than the grand mean and 9 trees showed mean seed weight to be higher than the grand mean (135.99 ± 0.3719 mg). There was slight tendency of mean seed weight to be negatively skewed among the trees. The distribution of seed weight for individual *Thespesia* trees was distributed unevenly around the grand mean value. This may perhaps be attributed to the environmental heterogeneity associated with these trees. Under controlled environmental conditions, Thompson (1984) has reported the distribution of mean seed weight in *Lamatium grayi* (Umbelliferae) around the grand mean of seed to be non-skewed and significantly leptokurtic.

The mean seed weight for a mean tree representative to a plant size class based on the stem diameter varied from 120.35 mg for size class E (> 25 cm stem diameter) to 148.74 mg for size class B (10 – 15 cm stem diameter). The variation of seed weight among and within classes was more or less equal in magnitude. Seed mass of Scots pine per maternal plant has been reported to be determined by maternal plants (seed mass varying from 7.2 to 14.0 mg with little variation within plants) (Castro, 1999; Debain *et. al.*, 2003). Mean seed mass is known to be significantly lower in wild accessions of *Salvia hispanica* L. than that in its cultivated accessions (Cahill and Ehdaie, 2005). Differences in mean seed weight in individual plants could be due to differences in environmental conditions e.g., nutrients, light, water or salinity level to which individual mother plants could have been subject during recent period of floral development and growth and seed development and maturation (Gutterman, 1992). Drought during pod filling has been reported to significantly affect seed weight in *Acacia* species (Gaol and Fox, 2002) and *Vicia faba* (Xia, 1997). Fecundity is substantially limited by short resource availability (Fenner and Thomson, 2005).

The mean weight of individual seed was found to be 135.99 ± 0.3719 mg with coefficient of variation among the seed weights, 22.71%. Michaels *et. al.* (1988) have examined 39 species (46 populations) of plants in eastern-central Illinois and reported variability (in terms of Cvar %) of seed mass commonly exceeding 20% - significant variation being among the conspecific plants in most species sampled. Magnitude of variation of seed weight among plants may arise due to several reasons (Wulff, 1986a; Busso and Perryman, 2005). Khan *et. al.* (1984) have reported seed weight variation in terms of Coefficient of variation to be 6.82 % in *Achyranthes aspera*, 12.91% in *Peristrophe bicalyculata*, 14 % in *Cassia holosericea* and 16.83% in *Prosopis juliflora*. *Opuntia ficus-indica* exhibited seed weight variation c. 18.2% (Khan, 2006). Busso and Perryman (2005) have reported seed weight variation in sage brush in terms of coefficient of variability to lie between 26.31 and 31.75% amongst the sites and years of study. The 15 folds variation in individual seed of *T. populnea* is greater than that reported in several other species. Janzen (1977, 1978) reported 3.5 fold variation among fresh seed masses of 10 *Cassia grandis* trees and 1.9 fold variations among 18 *Ateleia herberet-smithii* trees. Sachaal (1980) found 5.6 fold variation among 659 seeds collected from a population of *Lupinus texensis*. Our results are, however, comparable to 15.8 fold variation among seed masses in *Lamatium grayii* (Thompson, 1984). Large and small seeds differing two-fold in weight are reported in fire-prone *Cistus ladanifer* by Delgado *et. al.* (2007). Approximately 79.29% of the total variation in seed mass was within trees and 20.73% between the trees. This is similar to the results reported by Turnbill et *al.* (2006) in *Ceratonia siliqua* where the one-third of the seed mass variation occurred between trees and two-third among the trees. Howe and Richter (1982), however, demonstrated variation in seed size among plants to be more than the variation within plants in case of *Virola surinamensis*. Variation of seeds in a tropical plant, *Pithecellobium pedicellare*, was almost similar to that in *Virola* (Kang *et. al.*, 1992). In contrast *to P. pedicellare* and *V. surinamensis*, the studies conducted intemperate zone had shown variation in seed size within plants to be greater than among plants (Sachaal, 1980; Thompson, 1984; Mazer *et.al.*, 1986; Mc Ginley *et. al.*, 1990). O'Malle and Bawa (1987) found variation in seed size within and among plants to be more or less in equal magnitude. It is therefore likely that variation in seed weight is affected by maternal genetics and environmental effects both. Of course, it is difficult to weigh the relative importance of the two groups of factors. The large variation among plants suggests a potential for but not necessarily the presence of genetic control of seed size. This is because maternal parents may influence seed size via both maternal genetics and the maternal environment effect (Roach and Wulff, 1987). Obviously the seeds collected from the trees might be a mixture of half sibs and full sibs instead of strict half sibs.

Seed mass was traditionally considered to be the least plastic character (Harper *et. al.*, 1970). Wide intraspecific variations of seed mass have, however, been reported in several tropical tree species (Foster and Johnson, 1985; Khan *et al.*, 1984; Khan *et. al.* 1999, 2002; Khan and Umashanjkar, 2001; Murali, 1997; Marshall, 1986; Upadhaya *et. al.*, 2007) and other species as well (Wyllie-Esceverria *et. al*, 2003). There are reports of seed weight variation even within an individual plant (Sachaal, 1980; Hendriux, 1984). Seed size may be the result of myriad of factors (Fenner, 1985; Wulff, 1986a). Earlier impression of seed weight constancy in earlier ecological literature seems to be arising primarily from observations of the relative constancy of mean seed mass in some plant species rather than an analysis of the variability among individual seed masses which have demonstrated considerable variability. The analysis of means alone may, therefore, not realistically uncover the variability of seed masses in natural plant populations (Obeid *et. al.,* 1967; Thompson, 1984). Winn (1991) has suggested that plants may not have the capability of producing a completely uniform seed weight simply as a result of variations in resource availability (e.g., soil moisture during seed development). Seed size is significantly reduced under moisture stress in mature trees of walnut (Martin *et. al.,* 1980). Seed weight is said to be direct function of precipitation (moisture availability) and monthly precipitation is reported to explain around 85% of the total variation in seed weight in Wyoming sage brush (Busso and Perryman, 2005). Seed weight is also reported to decline with age in walnut (*Juglans major*) in terrace habitat of central Arizona (Stromberg and Patten (1990). It has also been reported to be the function of plant height in a population of *Ranunculus acris* (Totland and Birks, 1996).

Variation in seed mass against the number of seeds is generally viewed in terms of Smith-Fretwell theory (Smith and Fretwell, 1974) or recently proposed game theory (DeJong and Klinkhamer, 2005). Smith-Fretwell Theory (1974) proposed optimization model of allocation of resources where parents maximize their fitness producing seeds with a homogenous optimal size. Variation around the optimal size within an individual or a population could be related to the variation in parental size or quality of resources (e.g. McGinley, 1988), physiological, developmental or morphological constraints (e.g., Ginley *et. al*., 1987), parent offspring conflict and sibling rivalry (Uma Shankar *et. al*., 1988; Ganeshaiah and Uma Shankar, 1988). Since Smith-Fretwell model predicts optimum seed size expected in a particular ecological context, different optima for different individuals of a species may be expected, which may be the case when different individuals of *T. populnea* grew under differentially saline conditions.

The concept of optimal seed size in *T. populnea* has been extended by Ganeshaih and Uma Shankar (2003). They have propounded parent-offspring conflict in *T. populnea*. The offspring fitness in this species as measured by leaf area increases non-linearly with seed weight. The optimum level of resource at which the marginal returns to the mother is maximized is 165 mg (under south Indian environment). If the offspring conform to the maternal interest, then seed size in *T. populnea* should be normally distributed around this optimum. However, they found seed size distribution to be highly skewed in this species (as is the case in the present work also). It is suggestive of the fact that maternal parent and the offspring may have conflicting interests over the extent of resource allocation to seeds.

Seed size variation has been shown to have several important ecological implications. Seed mass is associated with seed germination (Baskin and Baskin, 1998; Navarro and Guitan, 2003), seedling vigour and survival, with both across species and within species (Arya *et al.,* 1992; Manga and Sen, 1996; Shaukat *et. al.,* 1999; Walters and Reich, 2000; Saeed and Shaukat, 2000; Vaughan and Ramsey, 2001; Halpern, 2005) presumably reflecting the amount of reserves available for early seedling growth (Castro *et. al.,* 2006). Heavier seeds produce heavy seedling with rapid pre-photosynthetic growth (Unival *et. al.,* 2008). Contrary to it, in some plants, larger seeds are not reported to give higher germination rate. In Glycine max, the higher rate of germination was, however, found to be related to smaller seeds (Tiwari *et. al.,* 1982). Espahbodi *et. al.,* (2007) has reported no significant correlation between seed size, seed weight and germination percentage in *Sorbus tormanalis*. Close and Wilson (2002) also found no correlation in seed weight and germination rate in *Eucalyptus delgatensis*. For some species carry over effects of seed size have been reported e.g., Ahmed and Zuberi (1973) reported in *Brassica campestris* L. var. *toria* that plants originating from smaller seeds produced smaller seeds than those originating from larger seeds. Seed size not only affects seedling success but also subsequent generation in *Desmodium paniculatum* (Wulff, 1986b). Larger seeds of *Telfaria occidentalis* are reported to be better adapted to cotyledon damage (Iortsuun *et al.,* 2008).

The seed fecundity varied greatly in *Thespesia* from plant to plant (16 – 29822). The younger plants produced very low number of seeds than that of mature plants. Amongst the mature plants largest seed crop was in B1 plant (size class C) of Boat Basin area (SN = 29822 seeds, SY= 4.47 kg) followed by a plant (size class D) of Karsaz area (SN = 22163, SY = 3.31 kg) corresponding with the larger number of capsules produced by these plants. Average number of seeds per mature plant was 8896.5 ± 1604.3 with coefficient of variability 80.65%. Average SY per mature plant was 1.25 ± 0.2169 kg – varying around 86.4%. It may be noted that variation in number of seeds produced by *T. populnea* trees was much higher than the variability exhibited by the seed weights of these plants on individual basis which ranged from 16.50 to 26.98% only. The variability of number of seeds in capsules per individual tree was also somewhat higher (18.19 to 55.43%) than seed weight variability. Our results in this respect are in close agreement with Harper's (1961) observation that there is far less variation in seed size than seed number among individuals in a plant species. It has strongly been supported by Smith and Fretwell's (1974) model of resource optimization.

The trees of size class D (20-25 cm stem diameter were the most productive. The average number of capsules, seeds and seed yield per plant gradually increased along the plant size and were maximum in plants of 20 – 25 cm stem diameter. These parameters, however, declined in larger plants of more than 25 cm stem diameter.

There was a substantial degree of multi-colinearity among the morphometric parameters. Untransformed data generally yielded low values of r which were greatly improved on $\log_e$ transformation of the X and Y variables. By virtue of this analysis height (H) of the *Thespesia* plants best related with Stem diameter (SD), Basal area (BA), Canopy volume (CV) and mean lateral branch diameter LM but comparatively poorly with reproductive variables. SD was very closely related with BA and moderately with (LM) and other variables. Number of main lateral branches yielded poor relationship. Live Crown ratio (LCR) correlated significantly negatively with H (r = -0.6940), SD (r = -0.5723), CD (-0.7282) and mean diameter of laterals, LM (r = -0.6268) i.e., LCR progressively declined with tree maturity. The estimated number of seeds per plant (SN) and total seed yield per plant (SY) related closely with number of capsules per plant (CP) but somewhat less closely with height (H). SN related positively significantly with BA. SY exhibited best fit relationship with BA and LM which itself correlated with BA very closely (r = 0.9424). The relationship of SN and SY with SD, BA, and LM were of general predictive value. However, among the three vegetative variables BA appeared to be more appropriate, particularly in case of SN.

Correlation among various plant parts is well known and considered to be of architectural significance in plants. Several authors have conducted such studies and reported significant results of great predictive value in functional ecological studies. Bella (1967) showed that there is a relationship between crown diameter and bole diameter at breast height. Kittredge as early as 1944 had indicated that leaf mass of the individual trees could be estimated by the function: log w = a + b log D, where w is the leaf weight and D is the bole diameter. Rogerson (1964) showed that foliage weight of loblolly pine was related to the tree diameter and projected crown area (the basal area in square feet of a horizontal crown profile when projected onto the soil surface). These two parameters accounted for 84% of the variation in data.

The allometric relations developed at individual plant, population, community or ecosystem levels are well exemplified in literature. Allometric relationships between crown diameter and bole diameter (Bella, 1967), between height and stem diameter (Yokozawa and Hara, 1995; Smith III *et al.,* 2006), plant height and leaf area (Akram-Ghaderi and Sultani, 2007), between plant size and density (Marshall, 1979; White and Harper, 1970; Niklas *et al.*, 2003), leaf area and basal diameter (Fownes and Harrington, 1991), basal diameter and wood (Ghezehi *et al.*, 2009) among various morphological parameters of plants such as height, stem width, leaf area, leaf length, leaf width, petiole length and leaf dry weight (Abu and Ali, 2005); between leaf mass and bole diameter (Akram-Ghaderi and Sulatani, 2007), in estimation of aboveground biomass or herbage or foliage estimation (Rogerson, 1964; Whittaker and Woodell, 1968; Martin *et al.*, 1980; Zianis and Mencuccini, 2003; Khan *et al.*, 2005; Maghambe *et al.*, 2006; Wang, 2006; Kirui *et al.,* 2006; Flombaum and Sala, 2007; Litton and Kauffman, 2008; Mbaekwe and Mackenzi, 2008; Basuki *et al.*, 2009; Ghezehi *et al.,* 2009; Tanaka *et al.,* 2009; Khan *et al*., 2010), between stem diameter and reproductive biomass (Niklas, 1993), in biomass partitioning (Niklas and Enquist, 2002; Enquist and Niklas, 2003), etc have been reported. Several significant allometric equations derived from simple linear and multiple linear and curvilinear regressions for logarithmically transformed data (Log_e) for fecundity (reproductive dependent variables such number of capsules per plant (ln CP), number of seeds per plant (ln SN) and seed yield (Kg) per plant (ln SY)) of *T. populnea* and its vegetative morphometric parameters as independent variables such as Height (ln H), Canopy diameter (ln CD), Canopy volume (ln CV), Stem diameter (ln SD) and Basal area (ln BA) were calculated. The independent parameters in their singular capacity although yielded statistically significant power equations with number of capsules per plant but they couldn't define more than 79.2 % of the total variation in data. The linear combinations of ln H with ln SD and ln CD with ln BA improved the relationship to account for around 83% of the variation in ln CP. The number of capsules per plant (ln CP) and estimated number of seeds per plant (ln SN) were found to be statistically ($p < 0.001$) best related with ln BA in curvilinear fashion. These quadratic power equations were not only statistically significant ($p < 0.001$) in respect of r, t, and F, also had high explanatory power to account for variation (around 91%) in number of capsules and seeds per plant. Loge transformed CP, SN and SY related significantly in curvilinear fashion with the complexity index (ln Ci) derived following the practice of Pool *et al.* (1977) and gave predictive equations with somewhat lower explanatory powers (81.4, 81.6 and 76.6%, respectively). Compared to the complexity index, therefore, stem diameter was a better morphometric parameter relating to the reproductive potential of the plant. This makes provision of calculating complexity index in relation to estimating fecundity in *T. populnea* relatively of lesser significance. It may, however, be mentioned here that present analysis is based on fecundity data for one year only. For more reliable relationships, observations on fecundity of *T. populnea* for several years may be necessary for more general application. In present case, most of the log-log predictive equations were curvilinear (quadratic). The causal factor for such a behaviour in not exactly known in *T. populnea*. Such relationships, however, seems to vary with the canopy shape in conifers. Broad-leaved type plants (more foliage mass in the upper layer than in the lower of the canopy of the individuals) are reported to exhibit curvilinear relationship between stem diameter (SD) and height (H) of the plant where as coniferous plants (more foliage in the lower layer than the upper layer exhibit almost linear relationship (i.e., simple allometry) between SD and H (Yokozawa and Hara, 1995). In three annual plants (*Impatiens pallida*, *Tagetes patula* and *Polygonum pansylvanicum*), allometric relationships between stem diameter, height, and plant biomass is generally simple (linear on log-log scale) when growing in isolation. When growing in crowding (competing), these relationships are curvilinear or discontinuous (Weiner and Thomas, 1992). In our studies stem diameter of *T. populnea* plants emerged as the most important structural predictive parameter of fecundity. Amongst various morphological plant parameters in trees, DBH has been found a better predictor of above ground organ mass of Norway spruce than height (Pokorný and Tomášková, 2007). Highly significant allometric regressions also resulted from using basal diameter and crown depth in *Jatropha curcas* L. (Ghezehei *et al*., 2009). Stem diameter provided better estimates for dry wood biomass in *Prosopis Juliflora* (Khan, 2011). Boehm *et al*. (2011) have found height (H) and shoot basal diameter (SBD) of young *Robinia pseudoacacia* to be closely related. They found that better estimation of yield is obtained when H and SBD were simultaneously related with single mass. It may, however, be mentioned here that present analysis is based on fecundity data for one year only. For more reliable relationships, observations on fecundity of *T. populnea* for several years may be necessary for more general application.

Average ECe of the soil and number of the seeds per capsule appeared to bear no correlation at all. The scatter diagram between these two variables although seems to reflect a curvilinear relationship between them, it appears not to be the case with the data in hand. Samples HB1 and HM of Hawkes Bay area, being smaller individuals entering reproduction first time but occurring in widely varying soil salinity, may definitely be considered as outliers in view of the halophytic nature of the plant. The scatter diagram sans HM and HB1 indicates no relationship between the two parameters ($r = 0.3612$). High salinity may, of course, affect the process of seed-setting or other related process (s) of fruit and seed development in several plants.

The average seed yield (g) per capsule of mature plants ($N = 20$), however, exhibited a curvilinear relationship with soil salinity (ECe; $dS.m^{-1}$), the plants were found to associate with which at the time of observation. ECe, this way, explained around 42% variation in the seed mass per capsule of *Thespesia* trees. The optimum level of ECe, in accordance with our results appeared to be around 32 $dS.m^{-1}$. The loge transformed seed yield per tree (kg) exhibited curvilinear relationship with canopy diameter (ln CD) and basal area (ln BA) significantly. The two parameters, however could only explain around 81% variation in seed yield. Average ECe of the soil and number of the seeds per capsule did not show any correlation at all. The high salinity may, however, affect the process of seed-setting or other related process (s) of fruit and seed development in many other plants.

As is the case with most of the allometric equations, irrespective of the fact of nature of the variables related to each other and the predictive significance of the equations, our equations being based on loge transformation of the variables, need a correction factor to be undertaken into consideration because such transformation introduces a systematic underestimation of the dependent variable (Y) when converting the estimated log back to original untransformed scale Y., Such a bias was recognized by Fenny (1941). Several authors (Baskerville, 1972; Bauchamp and Olsen, 1973; Yanale and Wiant, 1981; Duan, 1983; Sprugel, 1993; Zianis and Mencucinni, 2003) indicated a bias in estimation using logarithmic regression. The details regarding calculation of correction factor may be seen in Zianis and Mencucinni (2003). Furthermore, it may be emphasized that ecology of *T. populnea* in our arid coastal environment has not comprehensively been investigated. Great deal of work is needed to elucidate its ecology in this halo-xeric environment where in spite of its successful cultivation it is not forming natural populations. The probable loss of viability of seeds while still enclosed in capsule or inability of seeds to germinate under very high salinity or lack of dehiscence of capsule and their longer retention on plant, insect infestation, lack of any efficient means of dispersal of seeds, and other factors pertaining to its seed ecology, could be the factors to this effect.

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(*Accepted for publication June 2012*)