INT. J. BIOL. BIOTECH., 8 (3): 401-407, 2011.

LEAF AREA ESTIMATION IN *JATROPHA CURCAS* L.

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ABSTRACT

The graphically measured one-sided leaf area (LAM) of individual leaves of *Jatropha curcas* L varied from 9.48 – 158.55 cm^2 (mean = 72.094 ± 6.937 cm^2; CV = 56.93%). The leaf area (LAM) was found to correlate significantly with multiplicative parameter of leaf length and breadth (LL x LB) as simple linear model (R^2 = 0.983, F= 1955.64 ($p < 0.0001$) as well as the power model (R^2 = 0.9898; F = 2883.76 ($p < 0.0001$). Leaf area also correlated significantly with LL and LB linearly and combined in a multiple linear correlation / regression model (R^2 = 0.960; Adj. R^2: 0.958; F = 387.03 ($p < 0.0001$). The coefficient k estimated arithmetically as k = $\text{Area}_{\text{measured}}$ / (L x B) averaged to 0.858748 and distributed normally. On statistical comparison, the estimated leaf areas on the basis of above models were not found to vary significantly from the measured areas of the leaves (LAM). In view of simplicity and convenience, the method of using average k value of 0.858748 may be recommended for estimation of leaf area in *J. curcas.*

Key Words: *Jatropha curcas* L , Leaf area estimation, arithmetic and allometric models.

INTRODUCTION

Leaf area estimation is a time-consuming and laborious task. Various methods have been employed for leaf area estimation in several species (Kemp, 1960; Jain and Misra, 1966; Williams *et al*., 1973; Aase *et .al*., 1978; Hatfield *et. al.*, 1976; Elsner and Jubb, 1988; Chinamuthu *et. al*., 1989; O'Neal *et al*., 2002; Williams III and Martinson, 2003; Kathirvelan and Kalaiselvan, 2007, Cristofori *et al.*, 2007; Khan, 2008, 2009). Huxley (1924) was the first to demonstrate applicability of allometric methods in some grasses and Pearsall (1927) used allometric relationships in carrot and turnip to predict root storage through shoot growth estimation.

Jatropha curcas is economically important as one of the oil-yielding plant for industrial use (Shah *et al.*, 2005). In this paper, allometric relationship of leaf area of this species with such linear measurements as length and width of leaf is investigated besides generally employed arithmetic procedure for determining leaf area through calculation of mean multiplication coefficient (k) as employed by several workers (Kathirvelan and Kalaiselvan, 2007; Khan, 2008, 2009). This has been undertaken to develop a simple but efficient way of ascertaining leaf area in this species so that photosynthetic area of the crop plants may be determined in field experiments. Plant leaf area is directly related to light interception, photosynthesis, transpiration and carbon gain and storage. It is considered to be the most important single determinant of plant productivity (Linder, 1985; Kathirvelan and Kalaiselvan, 2007).

MATERIALS AND METHODS

Thirty five leaves of various sizes from healthy plants of *Jatropha curcas* crop grown under normal agricultural practice in the experimental field of Biosaline Research, department of Botany, University of Karachi, were collected and their linear measurements were recorded for the length of petiole, lamina length lying between the point of midrib insertion and the apex of the leaf (L) and lamina breadth (B) at the broadest points.

To determine true leaf area, the leaf outline was carefully drawn on graph paper and area determined with all possible precision and accuracy. The multiplication factor (K) was calculated by employing the formula, K = $\text{Area}_{\text{measured}}$ / (L x B). Employing average value of the multiplication factor k, leaf areas were calculated as $\text{Area}_{\text{computed}}$ = K (length x breadth) for comparison with the observed areas of the leaves. Bivariate linear and power relationships of leaf area with measured linear dimensions of the leaf were variously computed. In addition to it the regression coefficients were also determined by employing multiple regression method fitting in the allometric model, $Y = a + b_1X_1 + b_2 X_2 \pm SE$. The arithmetic and allometric methods were compared for their precision and suitability

RESULTS AND DISCUSSION

Petiole Length (PL)

PL varied with leaf size. It averaged to 10.71 ± 0.689 cm ranging from 3.20 to 18.0 cm in length (CV = 37.92%). Leaf area related with PL as power function of PL - highly significantly but its variation was accounted for by PL by a quantum of 85.3% only which was low from the viewpoint of leaf area estimation.

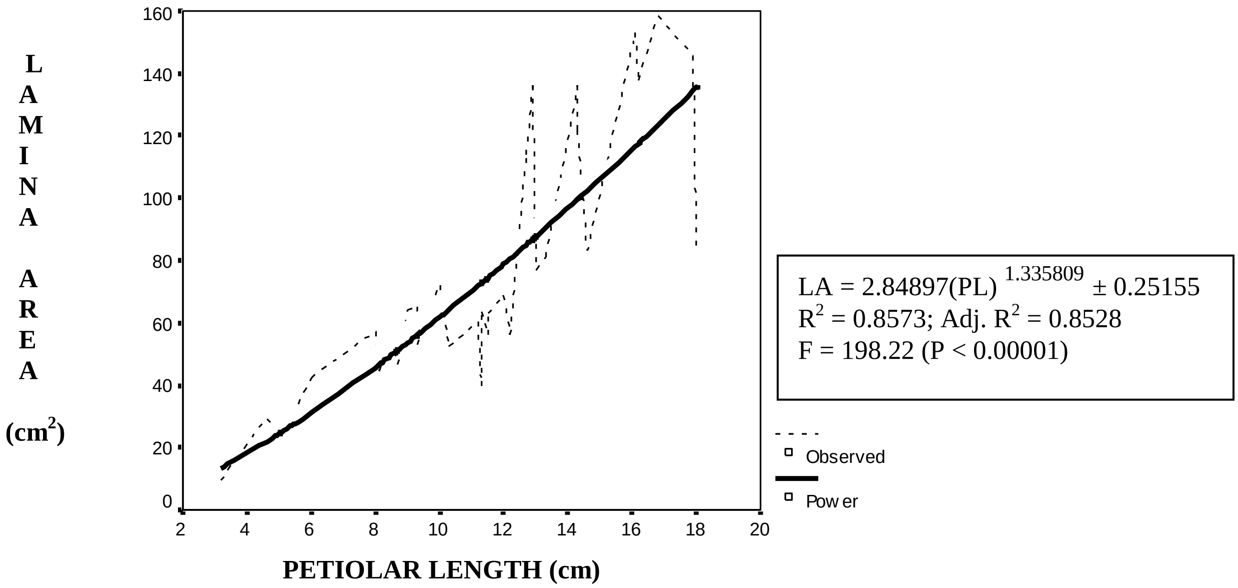


Fig. 1. Relationship of lamina area (LA) with the length of leaf petiole (PL).

Leaf Shape Consistency

L / B ratio gives some indication about consistency of leaf shape with size (Verwijst and wen, 1996). L / B ratio averaged to 0.8986 ± 0.0110 ranging from 0.76 to 1.13 (CV = 7.24%). Median (0.8854) was located near the mean. It follows from the data that leaves of *J. curcas* were generally and comparatively wider – only around 6% had LL/LB ratio equal to or slightly higher than 1.0 in magnitude (Fig. 2). The leaves were fairly consistent in shape as indicated by very low magnitude of CV.

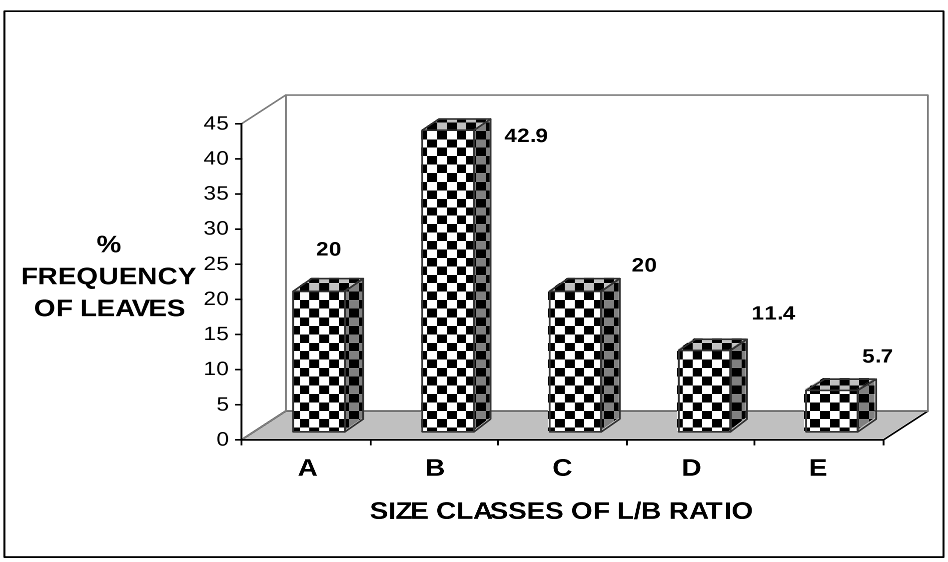


Fig. 2. Distribution of leaves among various size classes of Length / Breadth ratio. A, 0.76 – 0.85; B, 0.86 - 0.90; C, 0.91 – 0.95; D, 0.96 – 1.0 and E, ≥ 1.0.

Leaf length and Breadth

Leaf length varied from 3.5 to 13.60 cm (mean: 8.3 ± 0.4092; CV: 29.15%). Leaf breadth varied from 3.70 to 14.20cm (mean: 9.28 ± 0.4683; CV: 29.86%).

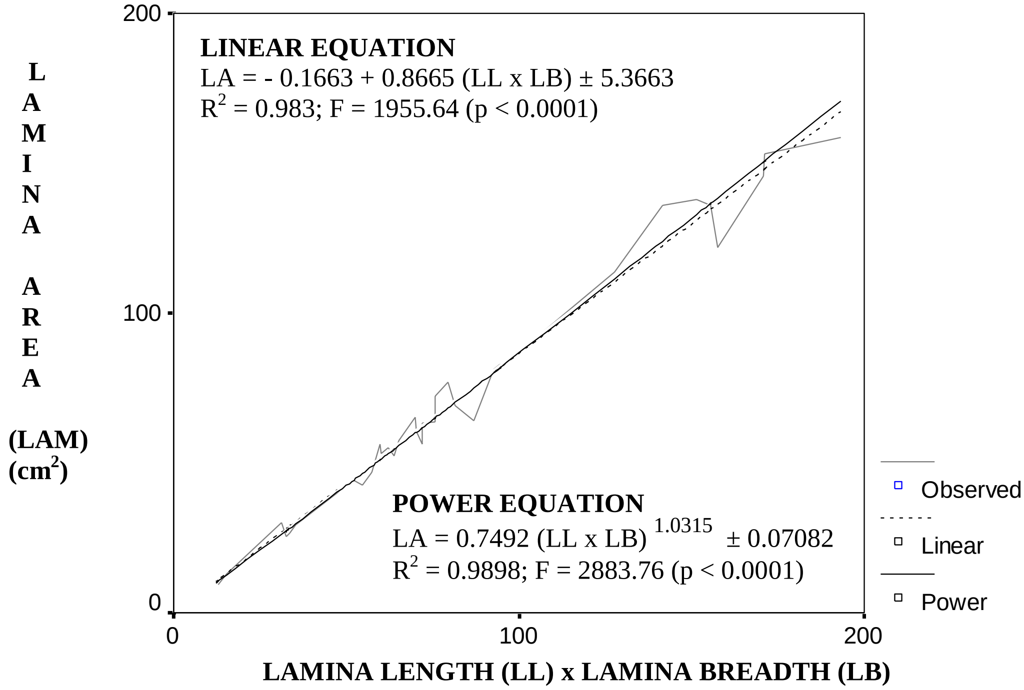
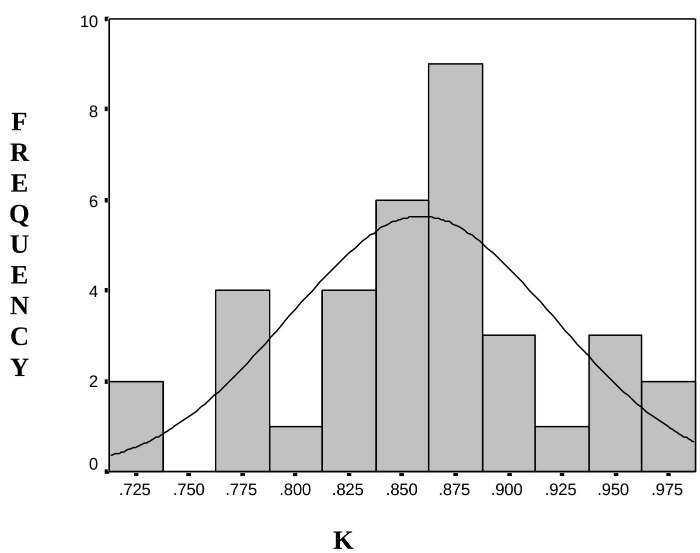


Fig. 3. Relationship between Area of lamina (LAM; cm^2) and Lamina length x Lamina breadth in cm. Both equations (Linear and power) are more or less equally significant.



N = 35
Mean = 0.858748
SE = 0.01044
CV (%) = 7.19%
Median = 0.8638
Skewness = -0.105
St. Error of skewness = 0.398
Kurtosis = -0.348
St. Error of Kurtosis =0.778
Minimum = 0.73, Maximum = 0.97
Kolmogorov-Smirnov Z = 0.512
(p < 0.956)
K-S d: 0.08684 (p < 0.466)
Lilliefors p > 0.20
Shapiro-Wilks W: 0.97081 (p < 0.466)

Fig. 4. Frequency distribution of coefficient k.

Leaf Area

Leaf area was measured graphically. The measured one-sided leaf area (LAM) varied from 9.48 – 158.55 cm^2 (mean = 72.0937 ± 6.937 cm^2; CV = 56.93%). The leaf area LAM was found to best relate with multiplicative parameter of LL x LB significantly as simple linear model as well as the power model as given below (see also Fig. 3).

LA = - 0.1663 + 0.8665 (LL x LB) ± 5.3663
R^2 = 0.983; F = 1955.64 ($p < 0.0001$) ……………………………………*Simple linear model*

LA = 0.7492 (LL x LB) $^{1.0315}$ ± 0.07082
R^2 = 0.9898; F = 2883.76 ($p < 0.0001$)………………………………………*Power model*

The leaf areas estimated though above linear and power models were designated as LALIN and LAPOW, respectively. The coefficient k was estimated as k = Area $_{measured}$ / (L x B). It averaged to 0.858748 and distributed normally (Fig.4). A new parameter of leaf area (LAMK) was thus generated arithmetically on the basis of average value of coefficient k (Area estimated = k (LL x LB). Linear simple and multiple regression models obtained by regression of LAM with LL and LB separately or in combination yielded following equations. The leaf areas calculated on the basis of the equation of multiple regression was designated as LAMULTI.

LAM = -64.717 + 16.493 LL ± 9.45
t = -10.84   t = 23.85
$p < 0.001$ $p < 0.001$
R^2 = 0.945, Adj. R^2 = 0.944, F = 568.93 ($p < 0.0001$)

LAM = -61.582 + 14.391 LB ± 9.86
t = -10.42   t = 23.58
$p < 0.001$ $p < 0.001$
R^2 = 0.972, Adj. R^2 = 0.944, F = 556.20 ($p < 0.0001$)

LAM = -65.428 + 8.534 LL + 7.180 LB ± 8.428
t = -12.68   t = 3.63   t = 3.49
p).0001 $p < 0.001$ $p < 0.001$
R^2 = 0.960; Adj. R^2: 0.958; F = 387.03 ($p < 0.0001$)……………..*Multiple Linear Regression Model*

Many workers have undertaken leaf area estimation allometrically as well as mathematically and have arrived at significant results with many species e.g., *Fragaria* spp. (Demirsoy *et al.* (2005); *Xanthosoma* spp. (Goenaga and Chew (1991); *Arachis hypogaea* (Kathirvelan and Kalaiselvan, 2007); hazel nut (Cristofori *et al*. (2007); millet (Persaud *et al.* (1993); *Prunus avium* (Citadani and Peri, 2006); in 15 fruit spp. (Uzun and Celik, 1999); sunflower (Bange *et al.* (2000), cotton (Akram-Ghaderi and Sultani, 2007), *Nicotiana plumbaginifolia (Khan, 2008)* and, *Ficus religiosa* (Khan , 2009). The fitness of power model to estimate leaf blade area has been reported in several species e.g., in *Coffea arabica* and *C. canephora* with high precision (R^2 = 0.998) and accuracy irrespective of cultivar and leaf size and shape (Atunes *et al*, 2008), in 'Niagara' (R^2 = 0.992) and 'DeChunac' (R^2 = 0.963) grapevines (Williams III and Martinson, 2003); groundnut (Kathirvelan and Kalaiselvan, 2007) and *Nicotiana plumbaginifolia* (Khan, 2008).

Table 1. Descriptive statistics of measured and estimated leaf areas.

Statistics	Measured Leaf Area	Estimated Leaf Areas			
	LAM	LAPOW	LALIN	LAMK	LAMULTI
Mean	72.094	72.174	72.098	71.617	72.033
St. Error	6.9371	7.0758	6.8797	6.8181	7.039
Median	63.140	61.721	62.222	61.830	60.688
CV (%)	56.93	58.010	56.45	57.01	57.81
Minimum	9.48	10.517	11.05	11.12	10.47
Maximum	158.55	170.777	167.172	165.840	167.21

Table 2. Paired sample test through t-test.

Pair	Paired Difference					t	Sig. (2 tailed)
	Mean	St. Deviation	SE	(95% CI) of the Difference			
				Lower	Upper		
LAM-LAPOW	-0.07980	5.495418	0.928388	-1.96655	1.80687	-0.086	0.932
LAM - LALIN	-0.00381	5.286787	0.893630	-1.81988	1.81226	-0.004	0.997
LAM-LAMK	0.47658	5.299173	0.895724	-1.34275	2.29691	0.532	0.598
LAM-LAMULTI	0.06106	5.524655	0.933837	-1.83673	1.95884	0.065	0.948

*, df = 34; CI: Confidence Interval.

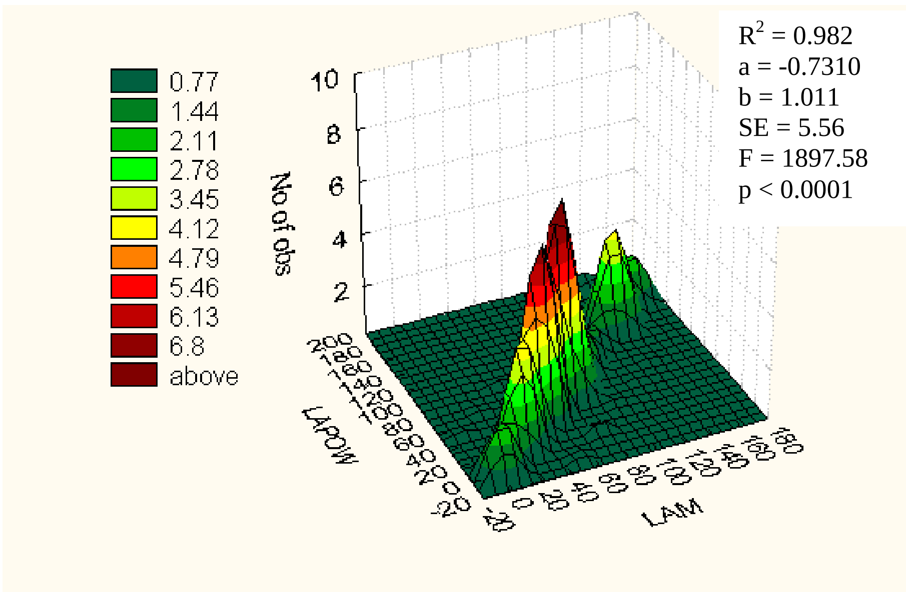


Fig. 5. Bivariate distribution diagram between LAM and LAPOW and the results of the linear correlation and regression analyses between these parameters.

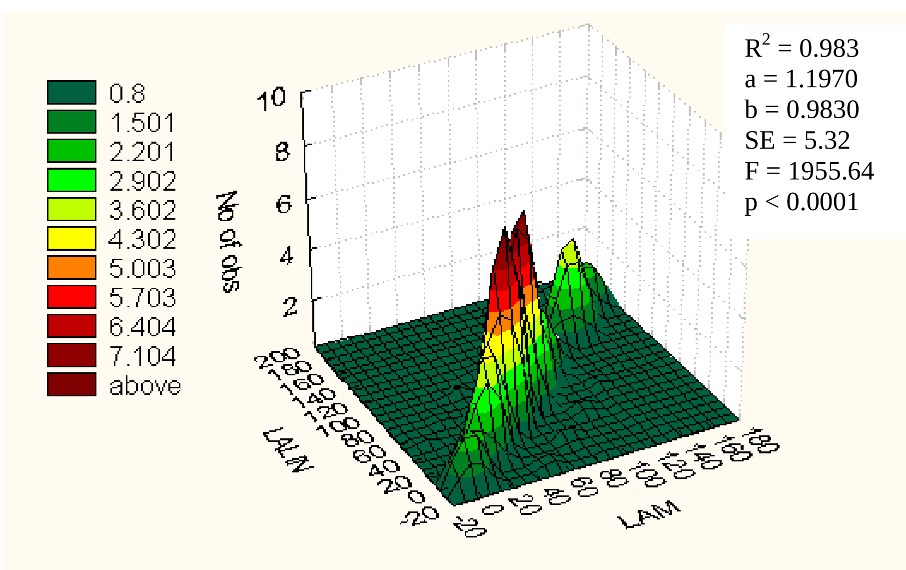


Fig. 6 Bivariate distribution diagram between LAM and LALIN and the results of the linear correlation and regression analyses between these parameters.

The variously estimated leaf areas (LALIN, LAPOW, LAMK and LAMULTI) were compared with the measured leaf area (LAM). The descriptive statistics of these parameters (Table 1), the paired sample test through t-test (Table 2), Bivariate distribution patterns between measured and estimated leaf areas (Fig. 5-8) and correlation and regression analyses between measured and variously estimated parameters (posted along the figures 5-8) indicated that statistically there was no significant difference between measured leaf area and the estimated leaf areas obtained through using various methods. All of the methods employed above appeared to be equally suitable to estimate leaf area in *Jatropha curcas* through such simple measurements as length and breadth of the leaves intact with the plant. . Owing to the simplicity and convenience, the method of using average k value of 0.858748 may be recommended for estimation of leaf area in *J. curcas.*

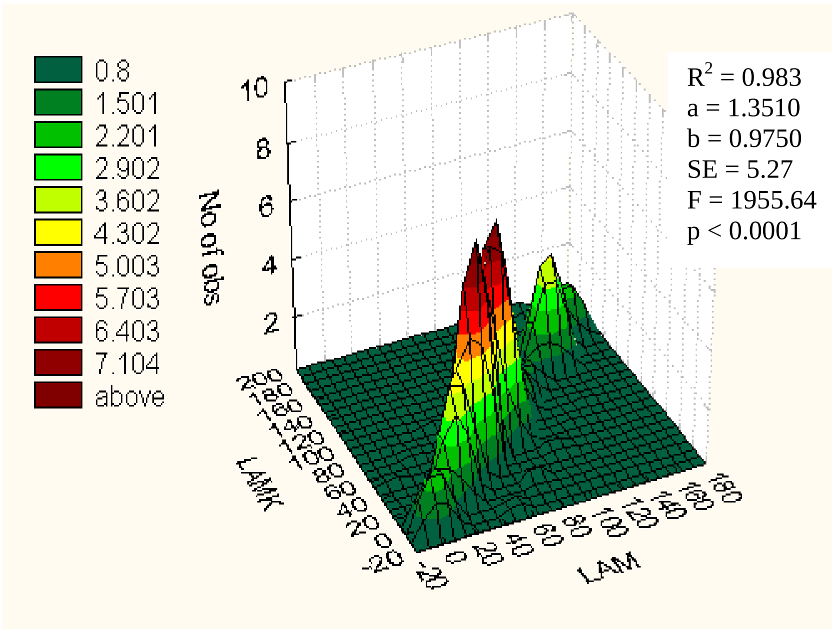


Fig.7. Bivariate distribution diagram between LAM and LAMK and the results of the linear correlation and regression analyses between these parameters.

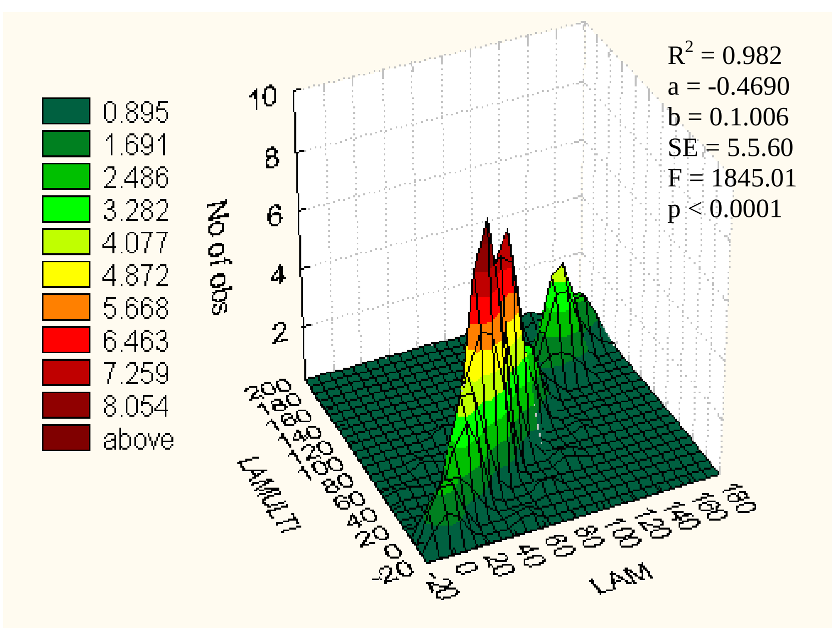


Fig. 8. Bivariate distribution diagram between LAM and LAMULTI and the results of linear correlation and regression analyses between these parameters.

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(*Accepted for publication June 2011*