Journal homepage
www.ajas.uoanbar.edu.iq
Anbar Journal of Agricultural Sciences
(University of Anbar – College of Agriculture)

MATHEMATICAL MODELS FOR ESTIMATING LEAF AREA OF APRICOT AND JUJUBE PLANTS BASED ON LEAF LENGTH AND WIDTH

M. E. A. Al-Hadethi [1]* **F. S. H. Al-Marsoumi [2]**

[1] Dept. of Hort. and Landscape, Coll. of Agricultural Engineering Sciences, University of Baghdad.
[2] Agricultural Research Office, Ministry of Agriculture, Iraq.

***Correspondence to:** Mustafa E. A. Al-Hadethi, Dept. of Hort. and Landscape, Coll. of Agricultural Engineering Sciences, University of Baghdad, Iraq.
Email: mustafa.e@coagri.uobaghdad.edu.iq

Article info

Received: 2024-10-10
Accepted: 2024-12-16
Published: 2024-12-31

DOI-Crossref:
10.32649/ajas.2024.154368.1448

Cite as:
Al-Hadethi, M. E. A., and Al-Marsoumi, F. S. H. (2024). Mathematical models for estimating leaf area of apricot and jujube plants based on leaf length and width. Anbar Journal of Agricultural Sciences, 22(2): 1610-1620.

Abstract

This research involved 14 apricot and 9 jujube cultivars from which 50 leaves each were taken for a total of 700 apricot and 450 jujube leaves. Leaf length and width were measured and leaf area (LA) calculated based on three methods: a square method drawing on graph paper; using a CI-202 area-meter device; and scanning and reading using a Digimizer program. The average leaf area from the three methods was calculated and linear regression analysis was used based on leaf length × width as independent variables. A mathematical model was then developed to calculate the leaf areas for both cultivar types. The coefficient of determination (R^2) values of the leaves were 0.155 and 0.998 for the local Zaghinia and Hamwi cultivars, while the MSE values were 0.071 and 34.273 for the Hamwi and Katy cultivars, respectively. For the LA models, the Hamwi cultivar model (LA= 0.6568 (LW) + 0.8683) was dominant. The general mathematical model estimated from this regression for the cultivars is LA= 0.6531 (LW) + 2.4147 with an R^2 of 0.976. As for the jujube plants, results showed that R^2 values were between 0.618 and 0.954 for the Basrah and Baghdad seed cultivars, while the MSE values were between 0.615 and 8.610 for the Mallasi and Tuffahy cultivars, respectively. Among the LR models, the

Armouty cultivar (LA= 0.6648 (LW) +1.7625) stood out. The general mathematical model estimated from this regression using the jujube cultivars is LA= 0.7528 (LW) + 0.0241 with R^2 of 0.987.

Keywords: Prunus armeniaca L, Zizphus spp., Cultivars, Regression LA.

نماذج رياضية لحساب مساحة الورقة في نباتي المشمش والسدر بالاعتماد على طول وعرض الورقة

مصطفى عيادة عداي الحديثي [1]* فاطمة سعد حميد المرسومي [2]

[1] قسم البستنة وهندسة الحدائق، كلية علوم الهندسة الزراعية، جامعة بغداد.

[2] وزارة الزراعة، دائرة البحوث الزراعية، العراق.

***المراسلة الى:** مصطفى عيادة عداي الحديثي، قسم البستنة وهندسة الحدائق، كلية علوم الهندسة الزراعية، جامعة بغداد، العراق.

البريد الالكتروني: mustafa.e@coagri.uobaghdad.edu.iq

الخلاصة

شملت الدراسة 14 صنف من المشمش و9 اصناف من السدر، اخذت 50 ورقة لكل صنف، اخذ 700 ورقة من المشمش و450 ورقة من السدر وقيس طول وعرض الورقة وحسبت مساحة الورقة لكل عينة بثلاثة طرق، الأولى طريقة المربعات بالرسم على الورق البياني، والثانية باستعمال جهاز CI-202 area-meter والثالثة باستعمال الماسح الضوئي ثم قراءة مساحة الورقة ببرنامج Digimizer. اخذ معدل مساحة الورقة الواحدة المحسوبة بالطرق الثلاثة أعلاه، واستعمل تحليل الانحدار الخطي اعتمادا على طول الورقة × عرضها كمتغيرات مستقلة، ووضع نموذج رياضي لحساب المساحة وللنوعين، أظهرت نتائج أوراق المشمش أن قيم R^2 كانت 0.155 للصنف زاغينيا المحلي و0.998 للصنف حموي، وقيم MSE كانت 0.071 في الحموي و34.273 في صنف كاتي. ومن بين نماذج LA هذه، كان نموذج صنف الحموي (LA= 0.6568 (LW) + 0.8683) هو الأفضل. النموذج الرياضي العام الذي قدرناه من هذا الانحدار باستخدام جميع أصناف المشمش المدروسة هو LA= 0.6531 (LW) + 2.4147 مع R^2 من 0.976. أما مساحة الورقة (LA) لنبات السدر، فقد أظهرت النتائج أن قيم R^2 كانت بين 0.618 لصنف البصرة البذري إلى 0.954 لصنف بغداد البذري، وقيم MSE كانت بين 0.615 لصنف الملاسي إلى 8.610 لصنف التفاحي. ومن بين نماذج المساحة هذه، كان نموذج صنف العرموطي (LA= 0.6648 (LW) +1.7625) هو الأفضل. النموذج الرياضي العام الذي قدرناه من هذا الانحدار باستخدام جميع أصناف السدر المدروسة هو LA= 0.7528 (LW) + 0.0241 مع R^2 بلغ 0.987.

كلمات مفتاحية: Prunus armeniaca L، Zizphus spp.، أصناف، انحدار، مساحة ورقة.

Introduction

Leaf area is generally considered an indicator of photosynthesis capacity as the green parts contribute to increasing the amounts of total dry matter production. Sunlight is the main source in most plant photosynthesis processes, and leaf area is important for determining the extent to which plants benefit from the light energy to which they are exposed. The final result is storage of plant dry matter, and since all parts of plants including stems, leaf sheaths, and other vegetative parts are green, they contribute to the photosynthesis process. As it is difficult to calculate the entire area of those parts only the leaf areas are used as they form the largest green portions of plants.

There are several methods for calculating plant leaf area, including cork drills and graph paper, as well as the more recent use of computer programs (2, 18 and 19). Plant production is also about using all scientific means to capture solar energy and convert it into food and other materials. Plant production strategies are usually designed to intercept the largest possible amounts of light and thus increase the photosynthesis process, which positively impacts their growth and yields. Fruit size development depends on elements such as leaf area and leaf-fruit ratio, as well as genetic and climatic factors, plant and branch positions, tree age, seed number, and water and nutrient supply (8, 12 and 19).

Various attempts have been made to develop mathematical equations for estimating leaf area along with leaf length and width. (6) found a study that determined leaf area in 21 European apricot varieties based on leaf length and width, arriving at the final equation LA=1.193+ 0.668 LW and a very high coefficient of determination R^2. A similar study by Ozturk et al. (16) on 12 pear varieties developed the equation LA= -0.433+0.715LW, with an R^2 of 0.987. Mhanna (13) studied the Khoderi olive cultivar to evaluate some mathematical measurement models for single leaf area estimations and dimensions (length and width). The R^2 was estimated at 0.962 and the linear regression equation of the mentioned relations gave an accuracy for the new model of A=e 0.9509ln LW - 0.2867.

The apricot tree, *Prunus armeniaca* L., belongs to the Rosacea family. Its history goes back 5,000 years in China, to the reign of Emperor Yu (10). Other sources indicate that its homeland is northern China, where it was grown 4,000 years ago (4). There are wild species whose cultivation extends from Japan to Afghanistan. The Romans called it the Armenian apple, giving rise to the belief that it originates from Armenia (20). The word apricot word goes back to the Greeks, where it was called Al-Praecox, which means early fruit (10). *Ziziphus* spp, known in English as jujube or ber, belongs to the Rhamnaceae family and the *Ziziphus* genus and contains more than 100 species of evergreen trees and shrubs that grow in the tropical, subtropical, and temperate regions of the world (21).

It is believed that original homeland of this plant is South and Southeast Asia, especially in regions extending from India to Malaysia (17). There is no doubt that it is one of the plants of Paradise, being mentioned in the Holy Qur'an, with economic and medicinal importance and many other benefits. Its fruits have much nutritional value due to their high content of ascorbic acid (vitamin C), carotenoids, and good

concentrations of sugars. Its trees also have many uses (15) and there is much global interest in growing them due to being relatively unexploited fruit trees, and ideal for agriculture in arid and semi-arid areas (17).

This study used multiple linear regression analysis for two fruit species to investigate an alternative to the complex traditional way of computing leaf areas based on their lengths and widths.

Materials and Methods

This study was conducted on 14 cultivars of apricots (Sabreen, Zaghinia, Qaisi, Winter, Syrian Herfy, Local Zaghinia, Kati, Bayaa, Palestinian, Labib, Hamwi, Zanjeel, Red Shine) as well as the seed apricot. Their leaves were brought from horticulture stations in Karbala and Hawija, except for the Zanjeel, Red Shine and seeding leaves which were sourced from the College of Agricultural Engineering Sciences of the University of Baghdad. For the jujube (*Zizphus* spp), nine cultivars were selected (Bambawi 1, Bambawi 2, Armouty, Tuffahy, Zaytony, Mallasi, and Seedless), in addition to two seed cultivars.

The leaves were brought from Basra, except for the seedless and one of the seed cultivars which were from Baghdad. Fifty leaves per cultivar were taken for both species, giving a total of 700 apricot and 450 jujube leaves. Leaf length (L) (cm) was measured from the tip to the petiole intersection while leaf width (W) was taken at the widest part (Figure 1). The leaf area for each sample was calculated based on three methods: the square method involved tracing the leaf on graph paper and calculating the area (Figure 2); the second method employed a device called the CI-202 area-meter (Figure 3); and the third involved a scanner and reading the leaf area using a Digimizer program (Figure 4).

The means for each leaf area using the three methods were determined and linear regression analysis applied by adopting length × width of each leaf as the independent variable. This mathematical model was then used to calculate the leaf areas for both cultivar types. The performances of the model was evaluated using standard error (SE), coefficient of determination (R^2), and mean square error (MSE). The above-mentioned calculations were carried out using Microsoft Excel program (7 and 1).

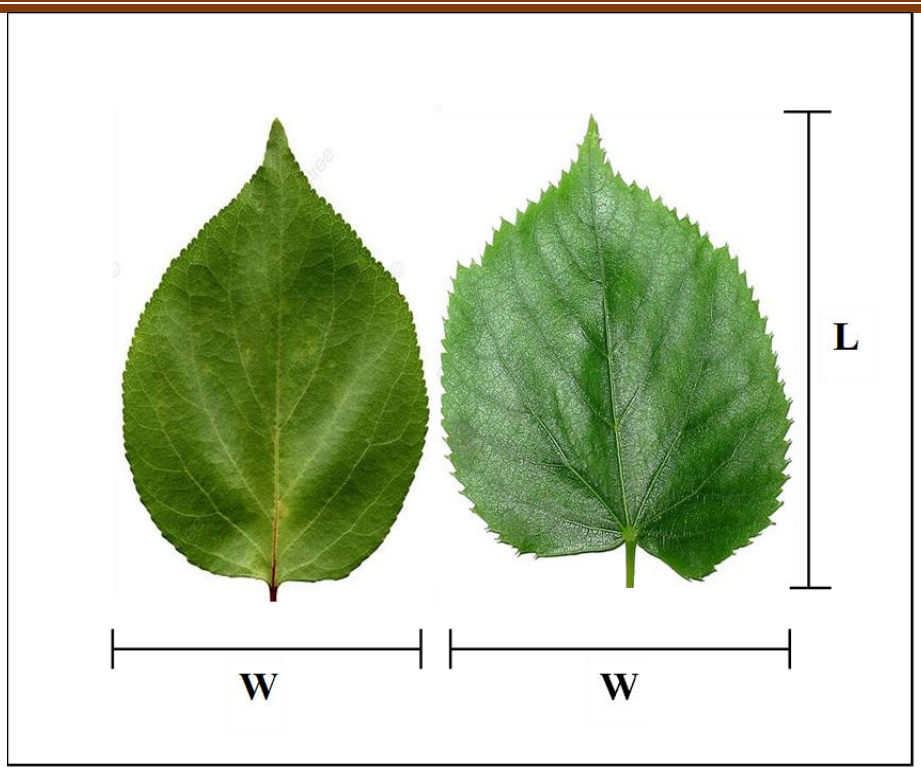

Fig. 1: Leaf width and length measurements.

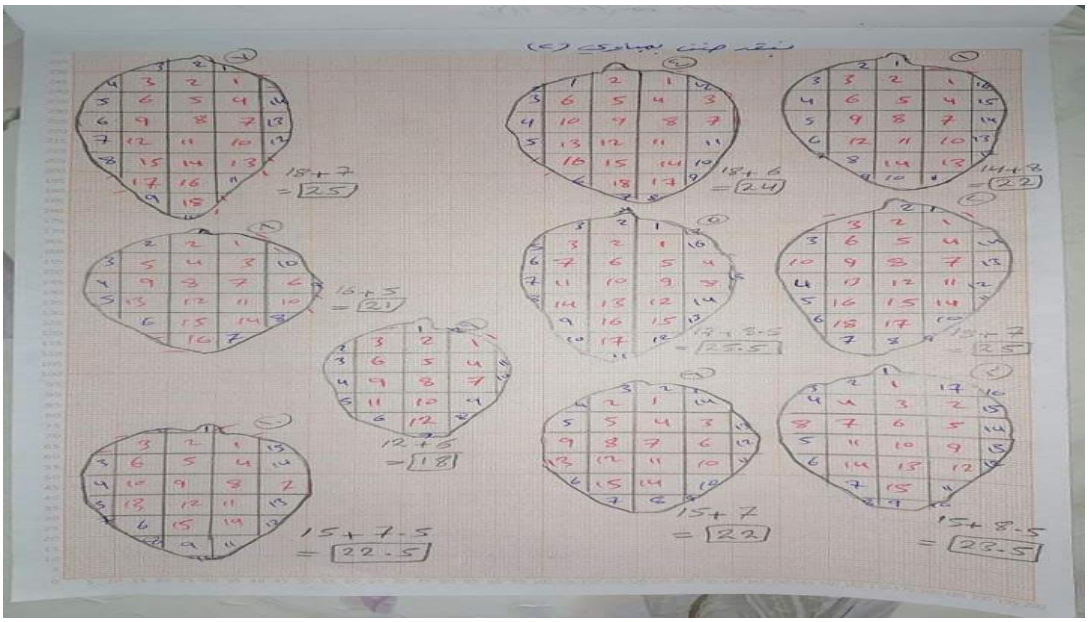

Fig. 2: Measuring leaf area using graph paper.

Fig. 3: A CI-202 area-meter.

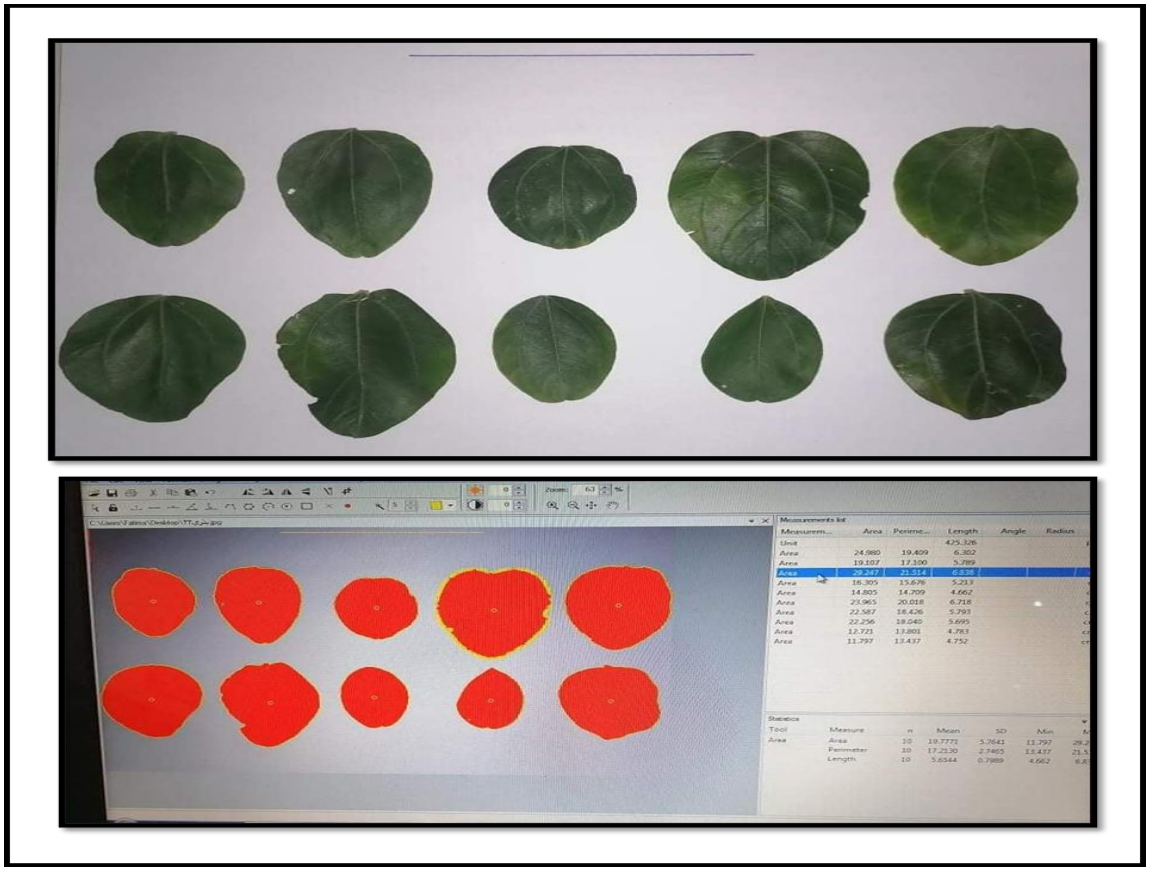

Fig. 4: Measuring leaf area using the Digimizer program.

Results and Discussion

Tables 1 and 2 show data on leaf length, width, and leaf area measured using the three methods, as well as average leaf area. The highest averages for leaf length, width, and area were in the Palestinian apricot cultivar at 11.48 cm, 9.98 cm, and 76.32 cm^2, respectively, while the lowest were in the seed cultivar at 3.92 cm, 2.94 cm, and 8.52 cm^2, respectively. The averages for all cultivar leaves were 7.26 cm, 6.25 cm, and 34.16 cm^2 for the same factors.

Table 1: Average leaf dimensions and areas of the apricot cultivars based on the three methods.

Cultivars	Leaf length (cm)	Leaf width (cm)	Leaf area methods			Average leaf area (cm^2)
			Graph paper	CI-202 area-meter	Digimizer program	
Sabreen	7.80	6.22	32.50	38.96	39.27	36.91
Zaghinia	6.42	4.94	21.00	23.12	29.43	24.52
Qaisi	7.66	6.28	32.40	34.59	34.86	33.95
Winter	9.14	7.72	50.80	58.27	58.80	55.96
S. Herfy	5.82	5.10	21.60	23.84	23.84	23.09
L. Zaghinia	5.32	4.86	17.40	18.83	18.57	18.27
Kati	9.58	9.06	58.20	53.65	55.23	55.69
Bayaa	7.64	6.72	34.06	31.69	31.63	32.46
Palestinian	11.48	9.98	80.90	72.72	75.33	76.32
Labib	7.66	6.68	35.30	32.43	32.98	33.57
Hamwi	5.40	4.70	20.00	17.24	16.12	17.79
Zanjeel	7.76	6.58	37.10	35.58	34.00	35.56
Red Shine	6.04	5.66	26.80	25.32	24.73	25.62
Seed cult.	3.92	2.94	9.72	8.15	7.688	8.52
Overall Average	7.26	6.25	34.13	33.89	34.46	34.16

Table 2 shows data for the jujube leaves with the highest average leaf length (8.90 cm) and area (34.37 cm^2) found in the Tuffahy cultivar while the highest width was in the Bambawi 1 cultivar (5.02 cm). Lowest average leaf length, width and area were in the Basrah seed cultivar at 4.87 cm, 3.37 cm, and 12.84 cm^2, respectively. The averages for all cultivars were 6.79 cm, 4.29 cm, and 22.21 cm^2 for the same variables, respectively.

Table 2: Average leaf dimensions and areas of the jujube cultivars based on the three methods.

Cultivars	Leaf length (cm)	Leaf width (cm)	Leaf area methods			Average leaf area (cm^2)
			Graph paper	CI-202 area-meter	Digimizer program	
Bambawi 1	7.55	5.02	28.05	27.60	27.60	27.72
Bambawi 2	6.90	4.58	22.85	23.11	23.31	23.08
Armouty	6.52	4.16	20.70	19.54	19.18	19.84
Tuffahy	8.90	4.95	35.20	34.13	33.74	34.37
Zaytony	7.96	3.93	23.90	23.11	22.57	23.23
Mallasi	6.13	4.10	19.60	19.18	19.05	19.27
Seedless	6.73	3.85	20.15	19.60	18.44	19.42
Bagh Seed	5.59	4.63	20.80	20.12	19.53	20.15
Bas Seed	4.87	3.37	13.25	12.67	12.66	12.84
Overall Average	6.79	4.29	22.72	22.12	21.79	22.21

Linear Regression Models (LR): The results in Table 3 show R^2 values of between 0.155 for the local Zaghinia and 0.998 for the Hamwi apricot cultivars, and MSE values of 0.071 to 34.273 for the Hamwi and Kati cultivars, respectively. Among these LR models, the Hamwi cultivar (LA= 0.6568 (LW) + 0.8683) was the best-rated, having the highest R^2 of 0.998 and lowest MSE of 0.071. The general mathematical models estimated for this regression for all the apricot cultivars was LA= 0.6531 (LW) + 2.4147 with R^2 of 0.976.

Table 3: Linear regression performance of the apricot cultivars.

Cultivars	SE	MSE	R^2	Model
Sabreen	1.970	3.881	0.983	LA= 0.8825 (LW) - 6.5703
Zaghinia	5.774	33.341	0.190	LA= 0.5366 (LW) +7.4437
Qaisi	2.223	4.943	0.964	LA= 0.7026 (LW) - 0.3891
Winter	2.528	6.389	0.994	LA= 0.8008 (LW) - 3.5991
S. Herfy	1.427	2.035	0.969	LA= 0.7693 (LW) - 0.1603
L. Zaghinia	0.445	0.198	0.155	LA= -0.0839 (LW) +20.433
Kati	5.854	34.273	0.565	LA= 0.3836 (LW) +22.221
Bayaa	1.298	1.685	0.490	LA= 0.4271 (LW) + 10.529
Palestinian	4.419	19.524	0.953	LA= 0.6996 (LW) - 4.5304
Labib	2.613	6.825	0.858	LA= 0.6485 (LW) + 0.2346
Hamwi	0.267	0.071	0.998	LA= 0.6568 (LW) + 0.8683
Zanjeel	2.610	6.812	0.936	LA= 0.7394 (LW) - 2.5746
Red Shine	0.834	0.695	0.970	LA= 0.6352 (LW) + 3.7395
Seed cult.	0.426	0.181	0.413	LA= 0.3783 (LW) + 4.1566
All Cultivars	2.919	8.523	0.976	LA= 0.6531 (LW) + 2.4147

As for the leaf areas (LA) of the jujube plants (Table 4), the R^2 values were between 0.618 for the Basrah seed and 0.954 for the Baghdad seed cultivars while the MSE values were between 0.615 and 8.610 for the Mallasi and Tuffahy cultivars, respectively. Of the LR models, the Armouty cultivar (LA= 0.6648 (LW) +1.7625) was the best with the second-highest R^2 at 0.920 and third lowest MSE at 0.720. The general mathematical model estimated for this regression for all the jujube cultivars was LA= 0.7528 (LW) + 0.0241 with R^2 of 0.987.

Table 4: Linear regression performance of the jujube cultivars.

Cultivars	SE	MSE	R^2	Model
Bambawi 1	1.649	2.718	0.878	LA= 0.6764 (LW) +1.9312
Bambawi 2	0.826	0.682	0.899	LA= 0.6078 (LW) +3.8475
Armouty	0.848	0.720	0.920	LA= 0.6648 (LW) +1.7625
Tuffahy	2.934	8.610	0.866	LA= 0.7087 (LW) +2.9294
Zaytony	0.873	0.763	0.900	LA= 0.758 (LW) - 1.514
Mallasi	0.785	0.615	0.882	LA= 0.6499 (LW) +2.9105
Seedless	0.877	0.768	0.908	LA= 0.6465 (LW) +2.5868
Bagh Seed	1.337	1.789	0.954	LA= 0.8286 (LW) - 1.6169
Bas Seed	1.842	3.393	0.618	LA= 0.5387 (LW) +3.9135
All Cultivars	0.741	0.549	0.987	LA= 0.7528 (LW) + 0.0241

This research developed a less complex and novel mathematical model for calculating leaf area (LA) and for conducting linear regression (LA) for apricot and jujube cultivars grown in Iraq. There were no significant differences found between leaf areas calculated using the three methods and predicted leaf area for any of the cultivars. As such, the mathematical models for the apricot (LA= 0.6531 (LW) + 2.4147) and jujube (LA= 0.7528 (LW) + 0.0241) cultivars can be used for physiological studies of these two plants.

These models can benefit researchers and specialists as they offer simple and quick measurements of the physiological processes in plants without adversely affecting large numbers of leaves of the fruit trees (3). Various researchers have employed this method on different fruit trees, such as Moghaddam (14) on two apple cultivars, Keramatlou et al. (11) on Persian walnut (*Juglans regia* L.), Boyacı and Küçükönder (5) on four apple cultivars, and Gonçalves et al. (9) of four guava (*Psidium guajava* L.) cultivars**.**

Conclusions

Based on the results of this study, it can be concluded that the general mathematical model estimated from this regression using the studied apricot cultivars is LA= 0.6531 (LW) + 2.4147, that for the jujube cultivars is LA= 0.7528 (LW) + 0.0241.

Supplementary Materials:

No Supplementary Materials.

Author Contributions:

Mustafa E.A. Al-Hadethi: methodology, writing-original draft preparation; F.S.H. Al Marsoumi: measuring the variables using the program and squares method.

Funding:

This research received no financial support.

Institutional Review Board Statement:

The study was conducted following the protocol authorized by the Head of the Ethics Committee, University of Baghdad, Iraq Republic.

Informed Consent Statement:

No Informed Consent Statement.

Data Availability Statement:

No Data Availability Statement.

Conflicts of Interest:

The authors declare no conflict of interest.

Acknowledgments:

We would like to thank Dr. Khawla Mohammed Hamza, professor at the College of Agriculture, University of Basra, for her assistance in providing the samples for the experiments. Our gratitude also to Mohammed Tariq Aziz of the Horticulture Department for his assistance in providing samples of the apricot leaves.

Disclaimer/Journal's Note:

The statements, opinions, and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of AJAS and/or the editor(s). AJAS and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions, or products referred to in the content.

References

1. Al-Asadi, M. H. S. (2019). Gen Stat for Agricultural Experiment Analysis. Al-Qasim Green University-Agriculture College. pp, 303.
2. Al-Dulaimy, F. Z., A., and A. Jubair, N. (2024). Improving Chemical Content of Date Palm Cv. Khastawi Under Different Levels of Spraying with Micro-Elements, Gibberellic Acid and Salicylic Acid. Anbar Journal of Agricultural Sciences, 22(1): 147-159. https://doi.org/10.32649/ajas.2024.146174.1115.
3. Al-Hadethi, M. E., and Almashhadani, B. M. (2019). Determination of some phenolic compounds in the leaves of some olive cultivars grown in Iraq. Plant Archives, 19(2): 4079-4083.
4. Al-hayani, M. A., and Al-Hadethi, M. E. (2023). Effect of Amino Acids Addition and Spraying with Glutathione and Kaolin in Growth Apricot Transplants. In IOP Conference Series: Earth and Environmental Science, 1262(4): 042025. DOI: 10.1088/1755-1315/1262/4/042025.
5. Alwan, J. M. (2017). Deciduous fruit technology. Propagation-cultivation-care and production (Part II).
6. Boyacı, S., and Küçükönder, H. (2022). A research on non-destructive leaf area estimation modeling for some apple cultivars. Erwerbs-Obstbau, 64(1): 1-7. https://doi.org/10.1007/s10341-021-00619-w.
7. Cirillo, C., Pannico, A., Basile, B., Rivera, C. M., Giaccone, M., Colla, G., ... and Rouphael, Y. (2017). A simple and accurate allometric model to predict single leaf area of twenty-one European apricot cultivars. Eur. J. Hortic. Sci, 82: 65-71. https://doi.org/10.17660/eJHS.2017/82.2.1.
8. Elsahookie, M. M., and Wuhaib, K. M. (1990). Design and analysis of experiments. Univ. of Bagh. Dar al Hekma. pp.488.
9. Fang, H., Baret, F., Plummer, S., and Schaepman-Strub, G. (2019). An overview of global leaf area index (LAI): Methods, products, validation, and applications. Reviews of Geophysics, 57(3): 739-799. https://doi.org/10.1029/2018RG000608.

10. Gonçalves, M. P., Ribeiro, R. V., and Amorim, L. (2022). Non-destructive models for estimating leaf area of guava cultivars. Bragantia, 81: e2822. https://doi.org/10.1590/1678-4499.20210342.
11. Janick, J. (2005). The origins of fruits, fruit growing, and fruit breeding. Plant breeding reviews, 25(1): 255-320. DOI:10.1002/9780470650301.
12. Keramatlou, I., Sharifani, M., Sabouri, H., Alizadeh, M., and Kamkar, B. (2015). A simple linear model for leaf area estimation in Persian walnut (Juglans regia L.). Scientia Horticulturae, 184: 36-39. https://doi.org/10.1016/j.scienta.2014.12.017.
13. Leroy, C., Saint-André, L., and Auclair, D. (2007). Practical methods for non-destructive measurement of tree leaf area. Agroforestry systems, 71: 99-108. https://doi.org/10.1007/s10457-007-9077-2.
14. Mhanna, M. A. (2020). Evaluation of new mathematical models for estimation of single olive leaves area. Agricultural Science and Technology, 12(2):144-147. DOI: 10.15547/ast.2020.02.024.
15. Moghaddam, P. A. (2014). Quick estimation of apple (Red Delicious and Golden Delicious) leaf area and chlorophyll content. Iran Agricultural Research, 33(1): 53-62. https://doi.org/10.22099/iar.2014.2381.
16. Nasri, M. B., and Nabli, M. A. (2006). Flora Biology study of Ziziphus lotus L. Acta Horticulture, 840.
17. Öztürk, A., Cemek, B., Demirsoy, H., and Küçüktopcu, E. (2019). Modelling of the leaf area for various pear cultivars using neuro computing approaches. Spanish Journal of Agricultural Research, 17(4): e0206. https://doi.org/10.5424/sjar/2019174-14675.
18. Pareek, O. P. (2001). Ber. International Centre for Under-utilized Crops, Southampton, UK.
19. Parker, G. G. (2020). Tamm review: Leaf Area Index (LAI) is both a determinant and a consequence of important processes in vegetation canopies. Forest Ecology and Management, 477: 118496. https://doi.org/10.1016/j.foreco.2020.118496.
20. Patil, P., Biradar, P., Bhagawathi, A. U., and Hejjegar, I. S. (2018). A review on leaf area index of horticulture crops and its importance. Int. J. Curr. Microbiol. App. Sci, 7(4): 505-513. https://doi.org/10.20546/ijcmas.2018.704.059.
21. Williams, J. T. (2006). Introduction, taxonomy and history. In: Williams, J. T., Smith, R. W., Haq, N., and Dunsiger, Z. (Editors), Ber and Other Jujubes. Southampton Centre for Underutilized Crops., Chap. 9: 1-17.