Pakistan J. Zool., vol. 54(3), pp 1087-1093, 2022 DOI: https://dx.doi.org/10.17582/journal.pjz/20200309160354

Usefulness of MARS and Bagging MARS Algorithms in Prediction of Honey Production in Beekeeping Enterprises from Elazig Province of Turkey

Murat Kulekçi[1], Ecevit Eyduran[2], Ayaz Yusuf Altın[2] and Mohammad Masood Tariq[3]*

[1]Department of Agricultural Economics, Agricultural Faculty, Atatürk University, Erzurum, Turkey
[2]Department of Business Administration, Faculty of Economics and Administrative Sciences, Igdir University, Igdir, Turkey
[3]Centre of Advanced Studies in Vaccinology and Biotechnology, University of Balochistan, Quetta, Pakistan.

Article Information
Received 09 March 2020
Revised 11 January 2021
Accepted 16 February 2021
Available online 05 May 2021 (early access)
Published 14 February 2022

Authors' Contribution
MK conceived and designed the study and collected the data. EE performed statistical analysis of the data. EE, MMT and AYA wrote the article.

Key words
MARS, Bagging MARS, Honey yield, Production economics, Honey bee

ABSTRACT

The present survey was conducted on beekeeping enterprises in Elazığ province of Turkey with the purpose of predicting honey yield per beehive via Multivariate Adaptive Regression Splines (MARS) and Bootstrap Aggregating Multivariate Adaptive Regression Splines (Bagging MARS) algorithms. To realize this purpose, a questionnaire form including several questions i.e. honey yield per beehive of enterprise, age of enterprise, educational level of enterprise, migratory status of enterprise (yes and no), other working area except for beekeeping (yes and no), number of full beehives and bee race (Caucasian and others), were elaborated. In MARS algorithm, no over-fitting problem was observed under a set of explanatory variables consisting of number of full beehives and total honey production, whereas Bagging MARS captured the interaction effects of number of full beehives with educational degree and other working areas. The constructed MARS and Bagging MARS models produced a marvelous fit in the prediction of honey yield per beehive. It was concluded that both algorithms were a good statistical tool to reveal tendency of beekeepers in the observed location and produced some considerable hints in increasing honey yield.

INTRODUCTION

Turkey is a country convenient for apiculture by the virtue of its appropriate ecology, rich flora and bee related biodiversity, and has wide variation in honey yield and production due to high genetic variability and different climate conditions (Çelik *et al*., 2016). Honey bee is an invaluable pollinator making the best of pollen and nectar sources from cultured and wild plants to fulfill its own requirements from nature and produces honey as a natural product for meeting human's body requirements. The pollination between wild grown and cultured plants occurred by honey bees is important in the sustainability of herbal products with high quality and quantity in the nature.

Honey production is a remarkable activity promoting rural development due to obtaining extra income, sustainability of biodiversity, fulfilling daily needs within family etc. and influenced by many factors i.e. floral composition, bee race, type of beehive, age and quality of queen (Al-Ghamdi *et al*., 2017), and beehive type (Vural and Karaman, 2010). Nyunza (2018) reported anthropogenic and climatic factors influencing honey production in Tanzania and gave information about loss of honey bee colonies, loss of foraging plants, insufficient water sources, unpredictable weather, grazing activities, increased charcoal burning, increased bush burning and high temperature as factors adversely affecting honey production.

The economic success of honey production depends on production technology and structure of income and expenses. Economic efficiency is represented by amount of output. Profitability of beekeeping is measured by the difference between the total revenues and total costs (Nedic and Nikotic, 2019). Labor costs form almost half of the expenses of production. Economics of honey can be assessed in two ways such as the honey production and food processing (bee wax, polen, royal jelly, propolis, bee venom, wax) etc., whereas beekeeping activity is used for pollination in the USA. Bee products are used

* Corresponding author: tariqkianiraja@hotmail.com
0030-9923/2022/0003-1087 $ 9.00/0

for medical purposes in Far East countries, while they are used for nutritional purpose in Europe (Saner *et al.*, 2018). In USA, honey production created 939 million $ value added to Food Processing Sector in 2017 (Matthews *et al.*, 2019). For the sustainability of profitability of honey production, there is a need for developing different pollination methods with different flower for winter in USA (DeGrandi-Hoffman *et al.*, 2019). Turkey is at second rank in production of honey with 7.900. 364 beehives after China. Especially after 2020, supply and demand of honey will be increased in Turkey, but supply of honey will be insufficient in obtaining the honey demand. The study of increasing supply should be conducted especially by training of beekeepers. The number of laboratories should be increased and against the risk of price fluctuation and a honey exchange should be established (Saner *et al.*, 2018).

Quality of queen bees, limited by genetic and non-genetic factors, is one of the most determinative factors affecting profitability of enterprises (Kosoglu *et al.*, 2017). Aksoy *et al.* (2017) reported that number of beehives, bee race, beekeeping type, variable cost and age of enterprise were factors affecting honey yield per hive. It was reported by Masuku (2013) that colony size and experience status of enterprise had a significant impact on honey yield as an indicator of profitability in apiculture.

To effectively define influential factors affecting honey yield and interaction effects between significant factors, better statistical techniques like multivariate adaptive regression splines (MARS) and ANNs (Artificial Neural Networks) algorithms may be chosen. MARS algorithm is a non-parametric regression technique that determines linear, non-linear and interaction effects of the influential factors affecting response variable like honey yield per beehive, without needing distributional assumption on all the used variables (Akin *et al.*, 2020).

Although MARS and CHAID algorithms have been used for the prediction of honey yield per beehive, but the best of our knowledge, there is no report yet on Bootstrap aggregating (Bagging) MARS technique to better describe the factors affecting honey yield per beehive. The current survey was conducted to exhibit factors influencing honey yield per beehive using MARS and Bagging MARS techniques.

MATERIALS AND METHODS

Data collection and sampling

The questionnaire data were obtained from 118 beekeeping enterprises at Elazığ province of Turkey in the prediction of honey yield per beehive. As also defined by Aksoy *et al.* (2017), the proportional sampling method was utilized for determination of suitable sample size in enterprises (Collins, 1986; Newbold, 1995).

Study area

For beekeeping activity, Elazig has a proper ecology with altitude reaching from 700 to 2600 meters. The region has a rich flora flowering in different flowering periods such as Thymus vulgaris, peppermint, Astragalus glycyphyllos, caprifole, robinia, deadnettle, catapuce, adam's flannel, alfalfa, trefoil, sunflower and eleagnus (Seven and Akkılıç, 2005).

The studied explanatory variables

In the prediction of honey yield per beehive (kg), several possible explanatory variables included in the current survey were age of enterprise, educational level of enterprise, other activities except for beekeeping (yes and no), number of full beehives, bee race (Caucasian and Other), honey production amount of enterprise (kg) and migratory status of enterprise (yes and no). Descriptive statistics of the studied variables are presented in Table I.

Table I. Descriptive statistics of the studied explanatory variables.

Variables	Mean±SE
Honey yield per beehive (kg)	5.26±0.26
Age of the enterprise (year)	47.65±0.97
Number of full beehives	89.03±5.28
Honey production (kg)	471.93±36.64
Educational level	Freq.(%)
Literate-illiterate	1(0.85)
Primary-Secondary school	52 (44.07)
High school	34 (28.81)
Bachelor	31 (26.27)
Migratory beekeeping status	Freq.(%)
Yes	43 (36.44)
No	75 (63.56)
Other works except for beekeeping	Freq.(%)
Available	95 (80.50)
Unavailable	23 (19.50)
Bee race	Freq.(%)
Caucasian race	95 (80.50)
Other races (Carniolan, Crossbred etc.)	23 (19.50)

Statistical analysis

With the intend of predicting honey yield per beehive from selected explanatory variables, Multivariate Adaptive Regression Splines (MARS) data mining algorithm as a modified form of Classification and Regression Tree (CART) algorithm was implemented in the current study. The current MARS predictive model with interaction term was constructed based on the lowest GCV (Akin *et al*., 2020). A ten-fold cross validation was considered as a resampling technique in the MARS modeling.

Bagging (Bootstrap aggregating) MARS algorithm uses bootstrapping among resampling techniques. Bagging models can provide their own internal estimate of predictive accuracy correlating well with either cross-validation estimates or test set estimates (Kunn and Johnson, 2013). A bootstrap sample (n) is a sample obtained randomly from the studied data on the basis of replacement. Some data points are selected multiple times in the bootstrap sample. The MARS model is constructed on the bootstrap sample and the predictive quality of the model was measured on the out of bag samples, which are data points not selected. Bagging MARS is a useful tool that is used to improve predictive accuracy of MARS model. Here, number of bootstrap samples was considered as 5.

The quality of all the MARS and Bagging MARS models in the study was evaluated using the goodness of fit criteria as mentioned by Zhang and Goh (2016) and Eyduran *et al*. (2019).

For MARS modeling, the earth package developed by Milborrow (2011) in R Studio software was specified (Eyduran *et al*., 2019; R Core Team, 2019). Also, ehaGoF package was used to measure predictive quality of MARS model (Eyduran, 2019).

RESULTS AND DISCUSSION

Results of the prediction equation produced by MARS and Bagging MARS algorithms are presented in Tables II and III. The desirable predictive quality of the MARS equation produced here was obtained with ensuring the smallest GCV (0.0381). The recorded or actual values in honey yield per beehive were correlated very strongly with those predicted by the MARS model ($P<0.001$) as a production modeling. For prediction equation of MARS model with 14 terms, no overfitting problem was recorded due to the fact that R^2 estimate (0.997) was very close to CVR^2 estimate (0.976). The current standard deviation ratio of 0.053 and MAPE of 3.659 indicated that the MARS model capturing only two influential factors i.e. number of beehive and honey production had an excellent fit. Some earlier authors informed that standard deviation ratio of the constructed model that had a very good fit should be less than 0.10 for regression type problems (Grzesiak and Zaborski, 2012; Eyduran *et al*., 2019). AIC and corrected AIC values for the constructed MARS model were estimated as -419 and -415. All the coefficients regarding MARS predictive model were statistically significant ($P<0.05$). To make easily interpretation, MARS terms numbered as 10-14 were ignored due to the fact that corresponding coefficients were very close to zero. For example, when number of full beehive was fewer than 58; max (0, NFB-58) = max (0, NFB-85) = max (0, NFB-125) = max (0, NFB-170) =0, which means that the influence of MARS terms numbered 2-4 and 6 on honey yield per beehive was masked.

For the enterprises with $58 < NFB < 85$ in number of full beehive, the influence of the second, third, fourth and sixth terms on honey yield per beehive was masked, but the effect of only fifth term and corresponding positive coefficient (0.11856) on the yield was likely to be positive.

For the enterprises with $85 < NFB < 125$ in number of full beehive, the effect of the second term and corresponding positive coefficient (0.08004) on honey yield per beehive was found positively; the effect of the third term and corresponding negative coefficient (-0.01668) on honey yield per beehive was found adversely; the influence of the fourth and sixth terms on honey yield per beehive was masked, but the effect of only fifth term and corresponding positive coefficient (0.11856) on the yield was likely to be positive.

For the enterprises with $125 < NFB < 170$ in number of full beehive, the effect of the second term and corresponding positive coefficient (0.08004) on honey yield per beehive was noted positively; the effect of the third term and corresponding negative coefficient (-0.01668) on honey yield per beehive was found adversely; the influence of the fourth and fifth terms as well as corresponding positive coefficients (0.02830 and 0.11856) on honey yield per beehive was positive.

For the enterprises with $NFB > 170$ in number of full beehive, the effect of the fifth term and corresponding positive coefficient (0.11856) on the yield was masked; an increment in the yield for the second and fourth terms would be expected due to corresponding positive coefficients, but a decrease for third and sixth terms would be expected due to corresponding adverse coefficients.

If honey production was less than 190 kg, the influence of MARS terms numbered 7 and 9 on honey yield per beehive was also masked, inferring that max (0, PRODUCTIONHONEY-190) and max (0, PRODUCTIONHONEY-330) became equal to zero; however, the eighth MARS term, max (0, 330-PRODUCTIONHONEY), and corresponding positive coefficient (0.03860) had a positive effect on honey yield per beehive.

When the seventh and eighth terms, max (0, PRODUCTIONHONEY-190) and max (0, 330-PRODUCTIONHONEY) as well as corresponding coefficients (0.03022 and 0.03860) were taken into consideration, an increment in honey yield per beehive would be expected for the enterprises with 190 < PRODUCTIONHONEY < 330 kg, whereas no effect of the ninth term, max (0, PRODUCTIONHONEY-330), on honey yield per beehive was masked regardless of its coefficient.

For the enterprises with PRODUCTIONHONEY > 330 kg, the influence of the eighth term on the yield was masked; however, the seventh term/ninth term had a positive effect/negative effect on honey yield per beehive.

Table II. Results of MARS model in the prediction of honey yield per beehive.

Terms	Basis function	Coefficients
1	Intercept	-14.98988
2	max(0, NFB-58)	0.08004
3	max(0, NFB-85)	-0.01668
4	max(0, NFB-125)	0.02830
5	max(0, 170-NFB)	0.11856
6	max(0, NFB-170)	-0.08633
7	max(0, PRODUCTIONHONEY-190)	0.03022
8	max(0, 330-PRODUCTIONHONEY)	0.03860
9	max(0, PRODUCTIONHONEY-330)	-0.03603
10	max(0, NFB-85) * PRODUCTION-HONEY	0.00013
11	max(0, NFB-170) * PRODUCTION-HONEY	-0.00016
12	max(0, 170-NFB) * max(0, PRODUC-TIONHONEY-205)	0.00022
13	max(0, 170-NFB) * max(0, 205-PRO-DUCTIONHONEY)	-0.00049
14	max(0, 170-NFB) * max(0, PRODUC-TIONHONEY-450)	-0.00002

Selected 14 of 14 terms, and 2 of 9 predictors; Termination condition: RSq changed by less than 0.001 at 14 terms.
Importance: NFB, Productionhoney, AGE-unused, EDUEL2-unused, EDUEL3-unused, EDUEL4-unused, Otherworksyes-unused, Raceother-unused, Migratoryyes-unused; Number of terms at each degree of interaction: 185; GCV= 0.0381; RSS= 2.68; GRSq= 0.995; RSq= 0.997; CVRSq= 0.976.

The predictive performances of the models built by Bagging MARS and MARS algorithms were found very close to each other. Interaction terms of number of full beehives and honey production were ignored due to very small corresponding coefficients in the Bagging MARS.

The prediction equation and detailed results of the Bagging MARS model is reported in Supplementary data.

Honey yield per beehive showed a decreasing tendency for the enterprises who performed other activities except for beekeeping and had NFB < 84 in number of full beehives. For the enterprises with primary-secondary school educational level (EDUEL2) and NFB <160, an increment in honey yield per beehive would be expected. Similarly, For the enterprises with high school educational level (EDUEL3) and NFB <60, an increment in honey yield per beehive would be also expected. The current bagging MARS results were partially in agreement with the statement of Abuje *et al*. (2017).

Table III. Goodness of fit criteria for MARS and bagging MARS algorithms.

	Criteria	MARS	Bagging MARS
1	Root mean square error (RMSE)	0.151	0.167
2	Relative root mean square error (RRM-SE)	2.864	3.207
3	Standard deviation ratio (SDR)	0.053	0.060
4	Coefficient of variation (CV)	2.880	3.220
5	Pearson's correlation coefficients (PC)	0.999	0.998
6	Performance index (PI)	1.433	1.605
7	Mean error (ME)	0.000	0.006
8	Relative approximation error (RAE)	0.001	0.001
9	Mean relative approximation error (MRAE)	0.002	0.003
10	Mean absolute percentage error (MAPE)	3.659	3.562
11	Mean absolute deviation (MAD)	0.106	0.107
12	Coefficient of determination (Rsq)	0.997	0.996
13	Adjusted coefficient of determination (ARsq)	0.997	0.996
14	Akaike's information cCriterion (AIC)	-418.743	-396.021
15	Corrected Akaike's information criteri-on (CAIC)	-414.666	-393.049

The current results were in disagreement with those reported by Aksoy *et al*. (2018), who evaluated predictive capabilities of OLS, CART, CHAID and MARS in the prediction of honey yield per beehive for the 180 beekeeping enterprises in Agrı, Erzurum and Kars provinces located in Eastern Anatolia region of Turkey, and reported that MARS had much better predictive capability in comparison with CART (age of enterprise (100%), other working areas except for beekeeping activity (58.9%), number of full beehives (57.6%), honey bee race (36.0%, province (25.9%), educational level (20.4%) and membership status (1.4%) in normalized significance order) and OLS (age of enterprise and other working areas except for beekeeping activity). Otim *et al*. (2018) reported that the influence of gender, age, educational status, beekeeping experience of enterprise, and training on honey production in Uganda was found insignificantly. Aksoy *et al*. (2018) could not produce CHAID-based regression tree, which was not in line with those obtained by Karadas and Kadirhanogulları (2017) in the prediction of honey yield per beehive.

The wide variation in literature may be due to genetic factors (bee race), non-genetic factors (flora composition, climate condition, quality of queen bee, frequency of altering queen bee, bee number of full beehive, type of beehive etc.), socioeconomic factors (age, educational status, experience, membership status of the beekeeping enterprise) and statistical factors (statistical techniques, sample size, variable structures (nominal, ordinal and scale), levels of factors and interaction degree) as also declared by some authors (Karadas and Kadirhanogulları, 2017; Aksoy *et al*., 2018). Kosoglu *et al*. (2017) emphasized significance of frequency of chancing queen bee as a prominent factor affecting the profitability in apiculture, which was not consistent with OLS results of Aksoy *et al*. (2018), but was in agreement with MARS results produced by Karadas and Kadirhanogulları (2017) within the framework of the honey yield prediction per beehive. Akin *et al*. (2020) prescribed that MARS captured linear, nonlinear and interaction effects of significant factors in regression type problems, as also highlighted by some earlier authors (Karadas and Kadirhanogulları, 2017; Aksoy *et al*., 2018) and those obtained in the current study.

Karadas and Kadirhanogulları (2017) reported that number of full beehives, working time spent in apiculture during year (day) and checking frequency of beehives in summer season were ascertained to be significant factors in regression tree structure built by Exhaustive CHAID data mining algorithm.

In disagreement with those given in the current study, Abuje *et al*. (2017) suggested that higher honey yield could be ensured with better conditions in respect to educational status, producer prices, credit facility, extension service, association membership as far as possible.

In disagreement with the current results, Aksoy *et al*. (2018) reported the influence of age of enterprise on honey yield per beehive varied based on number of full hives, location, other working areas, honey bee race, educational status, and membership status. Karadas and Kadirhanogulları (2017) found main and interaction effects of the following explanatory variables i.e. age of enterprise, educational level status, number of full beehives, time spent in plateau, autumn and spring feeding, working time spent in beekeeping activity in a year, and frequency of altering queen, which was not in agreement with the results of the current MARS analysis that captured main and interaction effects of honey production and number of full beehives as a significant explanatory variables without over-fitting problem (0.976 Cross validation R^2 very close to R^2 and adjusted R^2). This difference may be ascribed to overfitting problem that can be occurred in MARS. The problem is that MARS model includes redundant terms, which reduce predictive quality. In this context, the redundant ones should be removed by backward pruning method from the MARS model that has maximum complex structure in forward pass (Eyduran *et al*., 2019). The best way to understand overfitting problem is to estimate R^2 values for Cross validation, training and testing sets.

The MARS standard deviation ratio of 0.053 without overfitting problem in the current study was not in agreement with those estimated by Karadas and Kadirhanogulları (2017) for CHAID (0.639), Exhaustive CHAID (0.610), CART (0.667), ANN (0.463) and MARS (0.408). Grzesiak and Zaborski (2012) emphasized that a regression model constructed had a good fit or a very good fit if its standard ratio value is 0.40 or 0.10.

CONCLUSION

In the current study, beekeeping enterprises in Elazığ province of Turkey were evaluated to factors influencing honey yield per beehive on the basis of Multivariate Adaptive Regression Splines (MARS) and Bagging MARS algorithms showing perfect performance as a robust algorithm without overfitting problem. Bagging MARS successfully captured the interaction of educational level, working status in other activities except for beekeeping, with number of full beehives compared to MARS. To generate the achieved results, enterprises in more different ecologies need to be examined. However, it was concluded that MARS modeling was a good statistical tool to reveal tendency of beekeepers in the studied location and produced some valuable hints in increasing honey yield.

Supplementary material

There is supplementary material associated with this article. Access the material online at: https://dx.doi.org/10.17582/journal.pjz/20200309160354

Statement of conflict of interest

The authors have declared no conflict of interest.

REFERENCES

Abuje, V., Nyangweso, P., Mwakubo, S. and Chepng'eno, W., 2017. Determinants of honey production in Kenya; Case of Baringo County. *Afri.*

J. Agric. Environ., **3**: 1-19.

Ahmet, G.A. and Demir, M., 2015. Beekeeping potential in Turkey. *Bee World*, **86**: 114-119. https://doi.org/10.1080/0005772X.2005.11417326

Akin, M., Eyduran, S.P., Eyduran, E. and Reed, B.M., 2020. Analysis of macro nutrient related growth responses using multivariate adaptive regression splines. *Pl. Cell, Tissue Organ Culture* (PCTOC), **140**: 661–670. https://doi.org/10.1007/s11240-019-01763-8

Aksoy, A., Ertürk, Y.E., Erdoğan, S., Eyduran, E. and Tariq, M.M., 2018. Estimation of honey production in beekeeping enterprises from eastern part of turkey through some data mining algorithms. *Pakistan J. Zool*., **50**: 2199-2207. https://doi.org/10.17582/journal.pjz/2018.50.6.2199.2207

Aksoy, A., Sari, M.M. and Terin, M., 2017. Economic structure of beekeeping sector in Erzurum Province. *Turk. J. Agric. Nat. Sci*., **4**: 434-440.

Al-Ghamdi, A.A., Adgaba, N., Tadesse, Y., Getachew, A. and Al-Maktary, A.A., 2017. Comparative study on the dynamics and performances of Apis mellifera jemenitica and imported hybrid honeybee colonies in southwestern Saudi Arabia. *Saudi J. biol. Sci*., **24**: 1086-1093. https://doi.org/10.1016/j.sjbs.2017.01.008

Çelik, M.G., Kumova, U. and Kayaalp, G.T., 2016. Determination of some factors affecting honey yield by path analysis. *Turk. Sci. Technol*., **4**: 903-906. https://doi.org/10.24925/turjaf.v4i10.903-906.915

Collins, M., 1986. Sampling (eds. R.M. Worcester and J. Downhom, 1986). *Consumer market research handbook*. Elsevier Science Publishing Company Inc.

DeGrandi-Hoffman, G., Graham, H., Ahumada, F., Smart, M. and Ziolkowski, N., 2019. The economics of honey bee (Hymenoptera: Apidae) management and overwintering strategies for colonies used to pollinate almonds. *J. econ. Ent*., **112**: 2524-2533. https://doi.org/10.1093/jee/toz213

Eyduran, E., 2019. *ehaGoF: Calculates goodness of fit statistics*. R package version 0.1.0. https://CRAN.R-project.org/package=ehaGoF

Eyduran, E., Akin, M. and Eyduran, S.P., 2019. *Application of multivariate adaptive regression splines through R software*. Nobel Academic Publishing, Ankara.

Grzesiak, W. and Zaborski, D., 2012. Examples of the use of data mining methods in animal breeding. In: *Data mining applications in engineering and medicine* (ed. A. Karahoca). InTech, Rijeka, Croatia. pp. 303-324. https://doi.org/10.5772/50893

Karadas, K. and Kadirhanogullari, I.H., 2017. Predicting honey production using data mining and artificial neural network algorithms in apiculture. *Pakistan J. Zool*., **49**: 1611-1619. https://doi.org/10.17582/journal.pjz/2017.49.5.1611.1619

Kösoğlu, M., Yücel, B.Y., Özsoy, N., Topal, E. and Engindeniz, S., 2017. Effects of queen bee on colony development and management economy in Turkish beekeeping. *Turk. J. agric. Econ*., **23**: 55-60. https://doi.org/10.24181/tarekoder.325618

Kunn, M. and Johnson, K., 2013. *Applied predictive modeling*. NY. https://doi.org/10.1007/978-1-4614-6849-3

Masuku, M.B., 2013. Socioeconomic analysis of beekeeping in Swaziland: A case study of the Manzini Region, Swaziland. *J. Develop. Agric. Econ*., **5**: 236-241. https://doi.org/10.5897/JDAE2013.002

Matthews, W.A., Sumner, D.A. and Hanon, T., 2019. *Contributions of the U.S. honey industry to the U.S. economy*. National Honey Board, California, USA.

Milborrow, S., 2011. *Derived from MDA:MARS by T. Hastie and Tibshirani earth: Multivariate adaptive regression splines, R package*.

Nedic, N., Nikotic and Marija, M., 2019. Economic justification of honey production in Serbia. *J. agric. Sci*., **64**: 85-99. https://doi.org/10.2298/JAS1901085N

Newbold, P., 1995. *Statistics for business and economics*. Prentice-Hall International, New Jersey.

Nyunza, G., 2018. Anthropogenic and climatic factors affecting honey production: The case of selected villages in Manyoni District, Tanzania. *J. Agric. Biotech. Sustain. Dev*., **10**: 45-57. https://doi.org/10.5897/JABSD2017.0292

Otim, A.S., Kajobe, R., Kungu, J.M. and Echodu, R., 2018. The socio-economic factors influencing honey production in Uganda. *Glob. J. Agric. Res*., **6**: 1-9.

R Core Team, 2019. *R: A language and environment for statistical computing, version 3.0. 2*. Vienna, R Foundation for Statistical Computing, Austria, 2013.

Saner, G., Adanacıoğlu, H. and Naseri, Z., 2018. Forecasting honey supply and demand in Turkey. *Turk. J. agric. Econ*., **24**: 43-51. https://doi.org/10.24181/tarekoder.449992

Seven, I. and Akkılıç, M.E., 2005. The solution suggestions and determination of production and marketing problems of beekeeping enterprises in Elazığ Province). *J. Lalahan Livest. Res. Inst*., **45**:

41-52.

Vural, H. and Karaman, S., 2010. Socio-economic analysis of beekeeping and the effects of beehive types on honey production. *Afr. J. agric. Res*., **5**: 3003-3008.

Zaborski, D., Ali, M., Eyduran, E., Grzesiak, W., Tariq, M.M., Abbas, F., Waheed, A. and Tirink, C., 2019. Prediction of selected reproductive traits of indigenous harnai sheep under the farm management system via various data mining algorithms. *Pakistan J. Zool*., **51**: 421-431. https://doi.org/10.17582/journal.pjz/2019.51.2.421.431

Zhang, W. and Goh, A.T., 2016. Multivariate adaptive regression splines and neural network models for prediction of pile drivability. *Geosci. Front*., **7**: 45-52. https://doi.org/10.1016/j.gsf.2014.10.003