DOI: 10.29050/harranziraat.1025087

Harran Tarım ve Gıda Bilimleri Derg. 2022, 26(1): 1-14

Research Article/Araştırma Makalesi

First application of two distinguishment techniques: Using Linear Discriminate Function method and Artificial Neural Networks approach according to the ovary types for some plant parasitic nematodes

İki ayırt etme tekniğinin ilk kez uygulanması: Bazı bitki paraziti nematodların ovary tiplerine göre Doğrusal Ayırt Etme Fonksiyonu Yönteminin ve Yapay Sinir Ağları Yaklaşımının kullanımı

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To cite this article:
Tan, A.N., Tan, A. & Susurluk, H. (2022). First application of two distinguishment techniques: Using Linear Discriminate Function method and Artificial Neural Networks approach according to the ovary types for some plant parasitic nematodes. Harran Tarım ve Gıda Bilimleri Dergisi, 26(1): 1-14.
DOI:10.29050/harranziraat.1025087

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Received Date:
17.11.2021
Accepted Date:
18.02.2022

ABSTRACT

In this study mono and dual ovaries, which belonged to female individuals of different plant parasitic nematode species that were obtained from the quince (*Cydonia oblonga* Mill.) (Rosales: Rosaceae) cultivated areas in Sakarya Province (Turkey), were classified. The total number of 109 and 121 female nematodes, which were taken from the soil, were used in 2016, July and 2017, July, respectively. Overall body length (L), spear length (Stylet) and tail/distance from vulva to anus (T/VA) parameters belonged to these nematodes were measured and examined. The mono and dual ovary groups were distinguished by using the Linear Discriminate Function (LDF) method (Fisher's method) and Artificial Neural Networks (ANNs) approach taking correlation between those parameters into consideration. The pair of parameters L and (T/VA) had higher accuracy percentage (as 97% for LDF method and 100% for ANNs approach) than the pair of parameters L and Stylet (as 91% for LDF method and 97% for ANNs approach) for the classification using 2017, July data set. The second approach was more successful than the first method. This research is the first study that was used these method and approach together at the nematology study area in Turkey and the World. The taxonomical studies may be improved using different statistical methods and artificial neural networks approaches together at the nematology.

Key Words: Artificial Neural Networks, Linear Discriminate Function, Nematode, Ovary, Quince

ÖZ

Bu çalışmada Sakarya ilindeki (Türkiye) ayva (*Cydonia oblonga* Mill.) (Rosales: Rosaceae) ekiliş alanlarından elde edilen farklı bitki paraziti nematod türlerinin dişi bireylerine ait olan tek ve çift ovarileri sınıflandırılmıştır. Sırasıyla, 2016 Temmuz ve 2017 Temmuz' da topraktan alınan toplam 109 ve 121 adet dişi nematod kullanılmıştır. Bu nematodlara ait olan tüm vücut uzunluğu (L), stylet uzunluğu (Stylet) ve kuyruk/vulvadan anüse olan mesafe (T/VA) parametreleri ölçülmüş ve incelenmiştir. Tek ve çift ovary grupları, bu parametreler arasındaki ilişki dikkate alınarak Doğrusal Ayırt Etme Fonksiyonu Yöntemi (Fisher Yöntemi) ve Yapay Sinir Ağları Yaklaşımı kullanılarak ayırt edilmiştir. Temmuz 2017 veri seti kullanılarak yapılan sınıflandırmada L ve (T/VA) parametre ikilisi (LDF yöntemi için %97 ve YSA yaklaşımı için %100 olarak), L ve Stylet parametre ikilisinden (LDF yöntemi için %91 ve YSA yaklaşımı için %97 olarak) daha yüksek doğruluk yüzdesine sahiptir. İkinci yaklaşım, birinci yöntemden daha başarılıdır. Bu araştırma Türkiye'de ve Dünya'daki nematoloji çalışma alanında bu

yöntemin ve yaklaşımın birlikte kullanıldığı ilk çalışmadır. Taksonomi çalışmaları nematolojide farklı istatistiksel yöntemler ve yapay sinir ağları yaklaşımları birlikte kullanılarak geliştirilebilir.

Anahtar Kelimeler: Yapay Sinir Ağları, Doğrusal Ayırt Etme Fonksiyonu, Nematod, Ovary, Ayva

Introduction

The nematodes, which need to the water in a film layer for the survival, are alive individuals belonging to the Phylum Nematoda. The plant parasitic nematodes (PPNs) are the microscopic individuals that have important species among the plant pests which caused to the yield loss in the agricultural production. Further they are one of the Metazoan groups that are the richest in terms of species diversity in the Earth (Kareem et al., 2017).

The PPNs are available in the most of the agricultural areas in different climatic zones of the world widely. As Turkey has different climate types, it contains various plant and animal species. For this reason, many nematologists in our country have detected plant parasitic nematode species in host plants on different locations (Erdal et al., 2001; Yıldız and Mamay 2012; Kepenekçi, 2014). Further PPNs were determined on stone and pome fruits nurseries in Ödemiş (İzmir, Turkey) (Yıldız and Gözel, 2015).

In Turkey, fertile soils, favorable rainfall and climatic conditions allow the cultivation of all kinds of crops (Muminjanov and Karagöz, 2019). Since Turkey is the homeland of the quince is the leader with 174,038 tons and 6,568 ha of production area in the world and meets about 20% of world production (FAOSTAT, 2021). Sakarya province takes the first place in quince production with 102,476 tons and constitutes 59% of our country's quince production (TUIK, 2021). In this region Sakarya has a production potential that will be considered as the quince store in Turkey even the world (Aygün, 2018). As “Limon quince” kind got its name from the district of Geyve and it is a variety as a high table value known in the world market with the name as “Geyve Quince” (Gençer, 2011). Besides, “Eşme quince” is a kind of quince and is cultivated in Eşme District, Kocaeli Province, too (Bolat and İkinci, 2015). The Marmara Geographic Region is the first cultivated area at the quince cultivation in our country (Bolat and İkinci, 2015). Geyve Quince symbolized by Geyve on June 17, 2020 has been registered by the Turkish Patent and Trademark Office with geographical indication (Akal et al., 2020). The quince has a very important position used as the main material in the study and its sampling locations both in our country and in the world. So, we were collected the soil samples from quince cultivated areas in Sakarya (Turkey) and were examined.

PPNs have some taxonomic characteristic properties that can be distinguished by using the dimension and morphological similarity. Some morphometric measurement values are used in studies conducted for this purpose. Researchers should be aware of the importance of this issue in order to be able to diagnose nematode species using classical classification methods (De Oliveira et al., 2011). For this reason accurate identification has a great importance in understanding the diversity of nematodes, evaluating potential threats to plant health and deciding on efficient control methods. There are the body length, the morphology of genitals, the mouth and tail parts, and other some physical characters among important morphological identification characters at nematodes (Karssen and Van Aelst, 2001; Eisenback and Hunt, 2009; Bogale et al., 2020).

For example the morphology and the morphometric of the sexual organs are used for identification of nematode species in the classical taxonomic studies importantly. Generally the female nematodes are determined according to the mono ovary and dual ovary in a population together. For that reason it can cause some probable errors at the classification studies. In order to determine the number of real individuals in the study area, population catalogs should be classified truly. Parameters, that are present the nematode unaccompanied, are not enough to achieve. Many different methods exist in the

literature on the subject of discrimination of the population. Therefore the discrimination of the different groups should be examined carefully (Horasan et al., 2006). Linear Discriminate Function method and Artificial Neural Networks approach are two of discrimination techniques at the multidisciplinary scientific studies in the World (Dowla et al., 1990; Horasan et al., 2006, 2009; Küyük, et al., 2009; Kartal, 2010; Deniz, 2010; Kekovalı et al., 2010; Öğütçü et al., 2010; Kekovalı et al., 2012; Badawy et al., 2019; Ceydilek and Horasan, 2019; Tan et al., 2021a, b; Tan, 2021). But LDF method has not been used in the classification of the PPNs in the World, yet. We should point out that the LDF method firstly was applied by a biolog whom used flower morphometrics between two different species of *Iris* spp. (*Iris setosa* Pallas and Link and *Iris versicolor* L.) (Iris) for the group classification at the botanical studies in the literature (Fisher, 1936). Moreover it is determined as "The Fisher's method" in the statistics, too.

Besides, ANNs approach studies have been available and have showed that the artificial intelligence may be important in the detection, quantification as well as classification of nematodes (Ferrèe et al., 1996; Sundararaju et al., 2002; Li et al., 2016; Monteiro et al., 2016; Akintayo et al., 2018; Golhani et al., 2018; Aragon et al., 2019; Saberi et al., 2020; Uhleman et al., 2020).

In this study we used LDF method and ANNs approach together for discrimination of mono and dual ovary groups of the females PPNs population in quince which has had the most plantation area in Geyve and Pamukova in Sakarya Province during July, 2016 and July, 2017. The soil samples were collected from this study area and were examined. The location of the sampling area was shown in Figure 1. The values of accuracy percentage were calculated using these method and approach. Obtained data, that belonged to 2016 and 2017 years, was compared to determine the real number of the female ovaries. This may improve the quality of the population and help to better determination with less errors in nematode taxonomy studies by using some multidisciplinary scientific main brands together.

Material and Method

In this study, a total of 50 soil samples were taken from quince cultivation areas in Geyve and Pamukova in Sakarya in 2016, July and 2017, July in the region bounded by 39.48-40.00˚N and 30.03-30.21˚E. A total of identified 230 female of plant parasitic nematodes were diagnosed as And then they were diagnosed as *Helicotylenchus tunisiensis* Siddiqi 1963 (Tylenchida: Hoplolaimidae), *Merlinius brevidens* (Allen, 1955) Siddiqi, 1970 (Tylenchida: Belonolaimidae), *Pratylenchoides alkani* Yüksel, 1977 (Tylenchida: Pratylenchidae), *Rotylenchulus boreails* Loof and Oostenbrink, 1962 (Tylenchida: Hoplolaimidae) and *Scutylenchus quettensi*s Maqbool, Ghazala and Fatima, 1984 (Tylenchida: Belonolaimidae) for the plant parasitic nematode species with dual ovary and *Boleodorus (B.) thyllactus* Thorne, 1941 (Tylenchida: Tylenchidae), *Irantylenchus clavidoru*s Kheiri, 1972 (Tylenchida: Tylenchidae) and *Ditylenchus destructor* Thorne, 1945 (Tylenchida: Anguinidae) for the plant parasitic nematode species with mono ovary from these soil samples (Figure 1.). (Yakut et al., 2013).

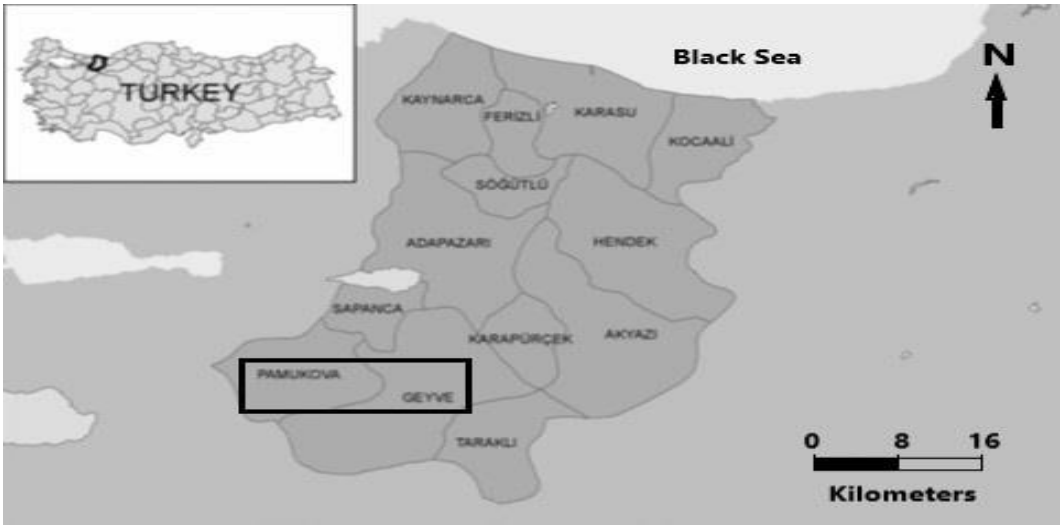

Figure 1. The location map of the study area as shown inside of the black rectangle (Modified from Yakut et al., 2013).

In this study, we used the parameters as overall body length, spear length, tail/distance from vulva to anus parameters (De Man, 1880) and compared the results of LDF method and ANNs approach for the classification of mono and dual ovaries. L versus Stylet, L versus (T/VA) were allowed the determination of LDF method using Statistical Package for the Social Sciences (SPSS) Analysis Program to discriminate mono and dual ovaries of this PPNs population (SPSS, 2005). Before we applied LDF method the data set, we have to recognize used some parameters as L, stylet and (T/VA). So we examined these parameters. We applied the normalization process to data after we calculated of these parameters. We used these parameters for discrimination of mono and dual ovary using LDF method and ANNs approach respectively.

LDF method

LDF method was used to discriminate different data groups from each other (Fisher, 1936). Generally Linear Discriminate Functions were shown as again simplified in "Equation 1":

$$F_{LDF} = a + b_1X_1 + b_2X_2 + \ldots + b_mX_m \qquad (1)$$

Here, a is constant number, b_1, … , b_m are regression coefficients and Xm is the value of independent variable m.

X_1: Normalized value of X_m discriminate parameters

L versus Stylet for the data set was drawn and we discriminated mono and dual ovary using LDF method. The functions were drawn and the accuracy percentages were calculated by using SPSS Analysis Program (SPSS, 2005). In this study we applied LDF method to the data set (Tables 1. and 2. and Figures 2. and 3.).

Table 1. The results of the discriminant analysis using LDF method for pairs of criteria 1: L versus Stylet and criteria 2: L versus (T/VA) parameters for data set in 2016, July. The original grouped cases were correctly classified for two criteria as 92% and 96%, respectively.

Criterion		Type	Predicted Group Membership		Total
			Dual Ovary (DO)	Mono Ovary (MO)	
1	Original Number	DO	59	5	64
		MO	4	41	45
	%	DO	92.2	7.8	100
		MO	8.9	91.1	100
2	Original Number	DO	64	0	64
		MO	4	41	45
	%	DO	100	0	100
		MO	8.9	91.1	100

Table 2. The results of the discriminant analysis using LDF method for pairs of criteria 1: L versus Stylet and criteria 2: L versus (T/VA) parameters for data set in 2017, July. The original grouped cases were correctly classified for two criteria as 91% and 97%, respectively.

Criterion		Type	Predicted Group Membership		Total
			Dual Ovary (DO)	Mono Ovary (MO)	
1	Original Number	DO	67	7	74
		MO	4	43	47
	%	DO	90.5	9.5	100
		MO	8.5	91.5	100
2	Original Number	DO	74	0	74
		MO	4	43	47
	%	DO	100	0	100
		MO	8.5	91.5	100

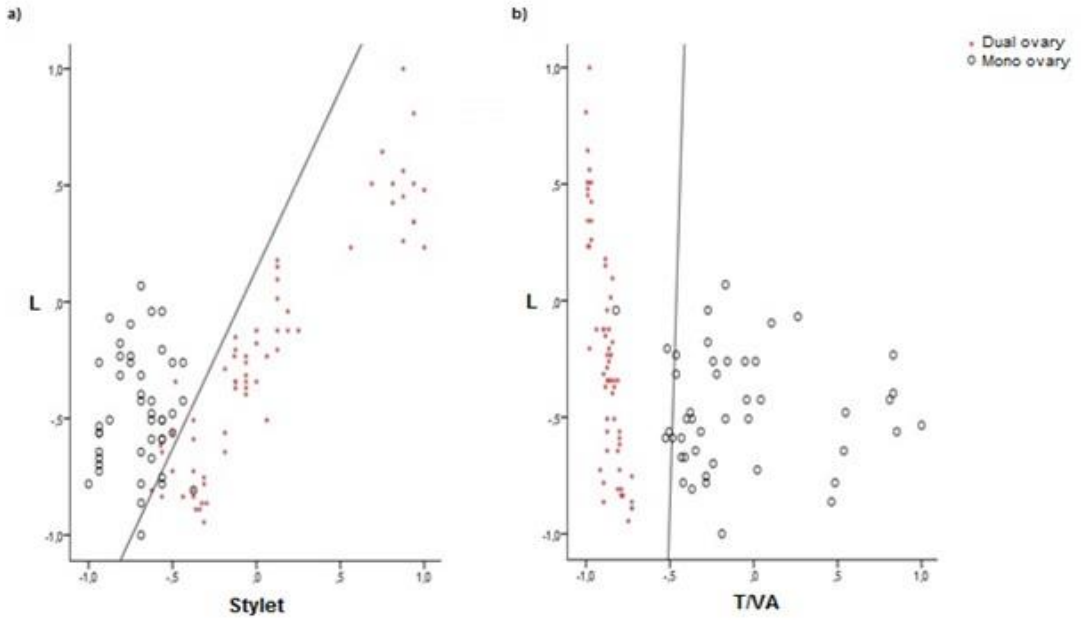

Figure 2. Plots showed distribution of a) L versus Stylet and b) L versus (T/VA) for data set using LDF method in 2016, July. The accuracy percentages were obtained as 92% for pairs of L versus Stylet parameters and as 96% for pairs of L versus (T/VA) parameters, respectively.

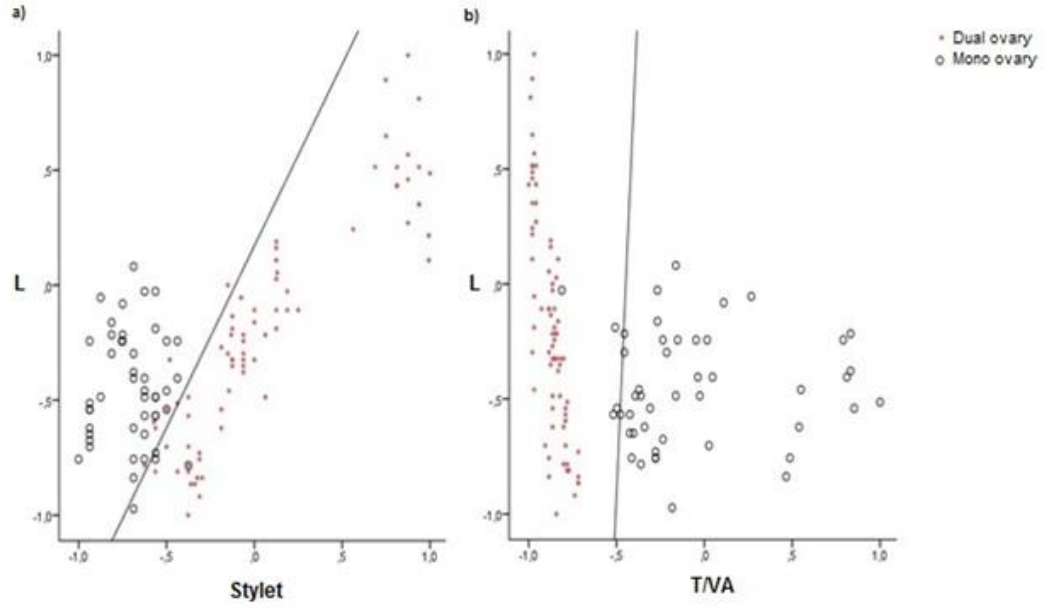

Figure 3. Plots showed distribution of a) L versus Stylet and b) L versus (T/VA) for data set using LDF method in 2017, July. The accuracy percentages were obtained as 91% for pairs of L versus Stylet parameters and as 97% for pairs of L versus (T/VA) parameters, respectively.

ANNs approach

We used the ANNs approach to compare the results of accuracy percentage of other method. This technique was applied to the data set. In this study we used Back Propagation Feed Forward Neural Networks (BPNNs) learning algorithm for the classification the morphometric measurements of PPNs. This algorithm had some advantages such as reducing error from backward namely output to input (Çetin et al., 2006). Further it had a simple neural network topology (Çayakan, 2012). And then, we decided to use weights according to the quantity of error (Yıldırım, 2013). Generally members of the network architecture were shown as in Figure 4 (Rumelhart et al., 1986; Gülbağ, 2006).

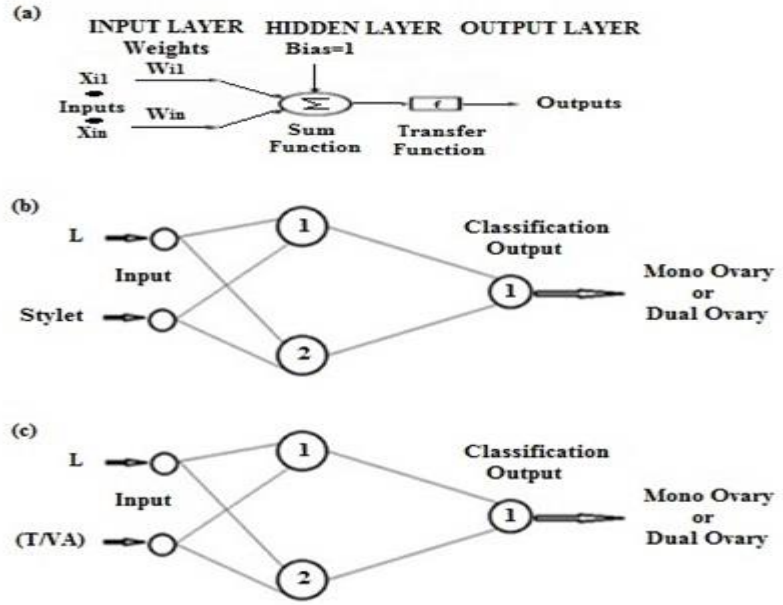

Figure 4. (a) Members of the network architecture, a neural network structure for types of the ovary (b) L versus Stylet and (c) L versus (T/VA) (Modified from Gülbağ, 2006).

Pairs of parameters were used in this study. Because one of them was the input parameter for testing and other was the output parameter as the type. These pairs of parameters were determined as L versus Stylet and L versus (T/VA), respectively (Figure 4.). We decided to use these pairs of parameters because of their high accuracy percentage according to the ANNs approach.

After we chose the learning algorithm, we started to prepare the data set as “the training data” and “the testing data” for ANNs approach. Different researchers prepared their data using values of different percentages for separating of training data and test data namely there is not a special rule for separating the data set (Ursino et al., 2001; Gülbağ, 2006; Yıldırım et al., 2011; Kundu et al., 2012; Yıldırım, 2013; Kaftan et al., 2017; Tan et al., 2021a, b; Tan, 2021). In this study we arranged the data set by using the 2016, July data and the 2017, July data. And then we have decided to use 70% of all data as training data and 30% of all data as testing data. The 2016, July data set had 109 and the 2017, July data set had 121 numbers for types of the ovary. We separated this data set to two parts as training data (Number of 76 data for the 2016, July data and Number of 85 data for the 2017, July data, respectively) and as testing data (Number of 33 data for the 2016, July data and Number of 36 data for the 2017, July data, respectively). Namely number of training data was of 70% using ANNs approach in this study (Tables 3. and 4.).

Table 3. Number of events in training set, testing set, misclassified testing set and misclassified quarry blast for all data set by using ANNs approach in 2016, July (For pairs of criteria 1: L versus Stylet and criteria 2: L versus (T/VA) for data set).

Criterion	The Number of All Data Set	The Number of Training Set	The Number of Testing Set	The Number of Misclassified Testing Set	The Accuracy Percentage (ANNs approach) (%)
1	109	76	33	2	94
2	109	76	33	0	100

Table 4. Number of events in training set, testing set, misclassified testing set and misclassified quarry blast for all data set by using ANNs approach in 2017, July (For pairs of criteria 1: L versus Stylet and criteria 2: L versus (T/VA) for data set).

Criterion	The Number of All Data Set	The Number of Training Set	The Number of Testing Set	The Number of Misclassified Testing Set	The Accuracy Percentage (ANNs approach) (%)
1	121	85	36	1	97
2	121	85	36	0	100

All results were obtained using ANNs approach on MATLAB (MATLAB, 2011). We obtained suitable results of accuracy percentage that had high values between 88% and 100% were obtained. Namely the results of ANNs approach were very successful. For obtaining the network architecture of the artificial neural network, the selection of the number of neurons (Nn) was an important criterion in the ANNs approach (Kermani et al., 2005; Gülbağ, 2006). Because it was one of the significant factors for the discrimination of different data groups (Çetin et al., 2006; Gülbağ and Temurtaş, 2007). Further Nn was decided by trial and error method (Yıldırım, 2013; Kaftan et al., 2017). And then Nn which had the highest accuracy percentage was selected for the defined ANNs model (Gülbağ, 2006). In the literature, researchers applied different intervals using different increments for Nn (Gülbağ, 2006; Küyük et al., 2009; Yıldırım, 2013; Kaftan et al., 2017; Tan et al., 2021a, b; Tan, 2021). In this study it was increased by 5 between 1 and 25 and then results were compared each other for every pair of parameters separately (Tables 5. and 6.).

Table 5. The number of neurons (Nn) according to the Accuracy Percentage results according to ANNs for pairs of criteria 1: L versus Stylet and criteria 2: L versus (T/VA) parameters in 2016, July.

Criterion	Accuracy (%) for Nn:5	Accuracy (%) for Nn:10	Accuracy (%) for Nn:15	Accuracy (%) for Nn:20	Accuracy (%) for Nn:25
1	88	94	94	94	94
2	100	100	94	100	100

Table 6. The number of neurons (Nn) according to the Accuracy Percentage results according to ANNs for pairs of criteria 1: L versus Stylet and criteria 2: L versus (T/VA) parameters in 2017, July.

Criterion	Accuracy (%) for Nn:5	Accuracy (%) for Nn:10	Accuracy (%) for Nn:15	Accuracy (%) for Nn:20	Accuracy (%) for Nn:25
1	94	94	97	92	94
2	100	92	97	100	97

The training was continued until the determination coefficient (R^2) has approximated to 1. When the suitable value was obtained, the network model was stopped and was started to the test (Tables 7. and 8.).

Table 7. The variation of R^2 according to Nn that were obtained using ANNs approach for pairs of criteria 1: L versus Stylet and criteria 2: L versus (T/VA) parameters in 2016, July.

Criterion	R^2 (Nn:5)	R^2 (Nn:10)	R^2 (Nn:15)	R^2 (Nn:20)	R^2 (Nn:25)
1	0.83	0.83	0.85	0.85	0.85
2	1	0.97	1	0.96	0.97

Table 8. The variation of R^2 according to Nn that were obtained using ANNs approach for pairs of criteria 1: L versus Stylet and criteria 2: L versus (T/VA) parameters in 2017, July.

Criterion	R^2 (Nn:5)	R^2 (Nn:10)	R^2 (Nn:15)	R^2 (Nn:20)	R^2 (Nn:25)
1	0.85	0.86	0.86	0.85	0.85
2	0.97	1	0.97	0.97	0.97

For the 2016, July data set we selected Nn as 10 for the pair of L versus Stylet and 5 for the pair of L versus (T/VA) parameters, respectively. Further for the 2017, July data set we selected Nn as 15 for the pair of L versus Stylet and 5 for the pair of L versus (T/VA) parameters, respectively. Because Nn was less for a pair of a parameter. Namely the architecture of the network was not complex and was close to 1 as R^2 (Tables 9. and 10.).

Table 9. The selected Nn according to the Accuracy Percentage results for pairs of criteria 1: L versus Stylet and criteria 2: L versus (T/VA) parameters in 2016, July.

Criterion	The Selected Nn	Accuracy (ANNs) (%)
1	10	94
2	5	100

Table 10. The selected Nn according to the Accuracy Percentage results for pairs of criteria 1: L versus Stylet and criteria 2: L versus (T/VA) parameters in 2017, July.

Criterion	The Selected Nn	Accuracy (ANNs) (%)
1	15	97
2	5	100

Further we used the Levenberg-Marquardt training algorithm and Hyperbolic Tangent-Sigmoid activation function in this study (Kermani et al., 2005; Küyük et al., 2009). This algorithm had an important application in MATLAB software (Levenberg, 1944; Marquardt, 1963; Charrier et al., 2007; MATLAB, 2011; James et al., 2017). The equations of the standard back propagation and the Levenberg-Marquardt (LM) algorithms were showed as selected activation function, denoted by $\varphi(x)$, defined the output of a neuron in terms of the induced local field (Gülbağ and Temurtaş, 2007). We might use the hyperbolic tangent sigmoid function, defined by using "Equation 2"

$$\varphi(x) = \frac{2}{1+e^{(-2x)}} - 1 \qquad (2)$$

Here, $\varphi(x)$: Hyperbolic Tangent Sigmoid activation function (Gradshteyn and Ryzhik, 2007).

Further the normalization process was applied to every data and a significant percentage of the data randomly had been selected as the training data. Hence remaining part was taken as the testing data, randomly (Kermani et al., 2005). After obtained outputs were compared with tested outputs, the accuracy percentage was calculated (Figures 5. and 6.).

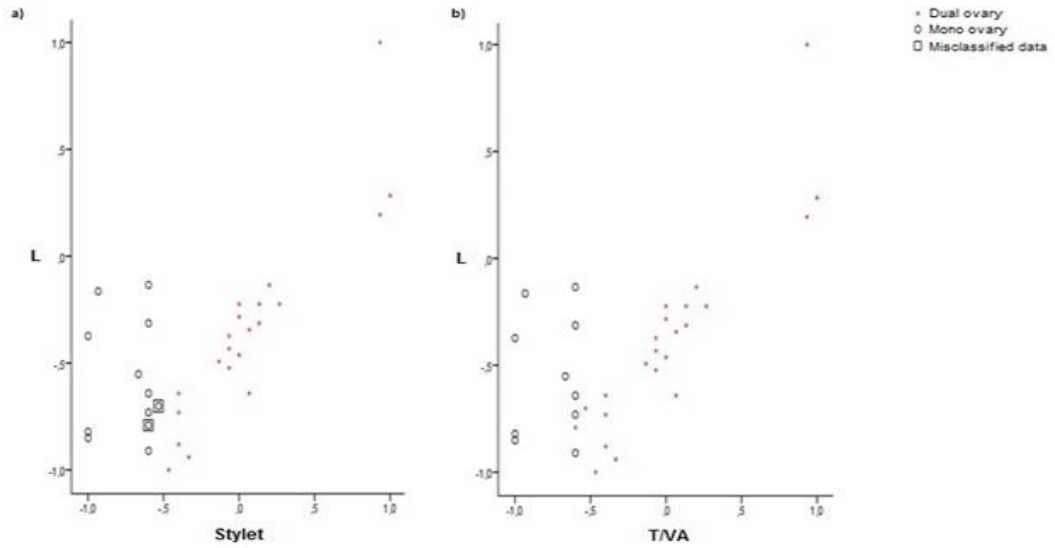

Figure 5. Plots show distribution of a) L versus Stylet (Selected Nn:10) and b) L versus (T/VA) (Selected Nn:5) for data set using ANNs approach in 2016, July. The accuracy percentages were obtained as 94% for pairs of L versus Stylet and as 100% for pairs of L versus (T/VA) parameters, respectively.

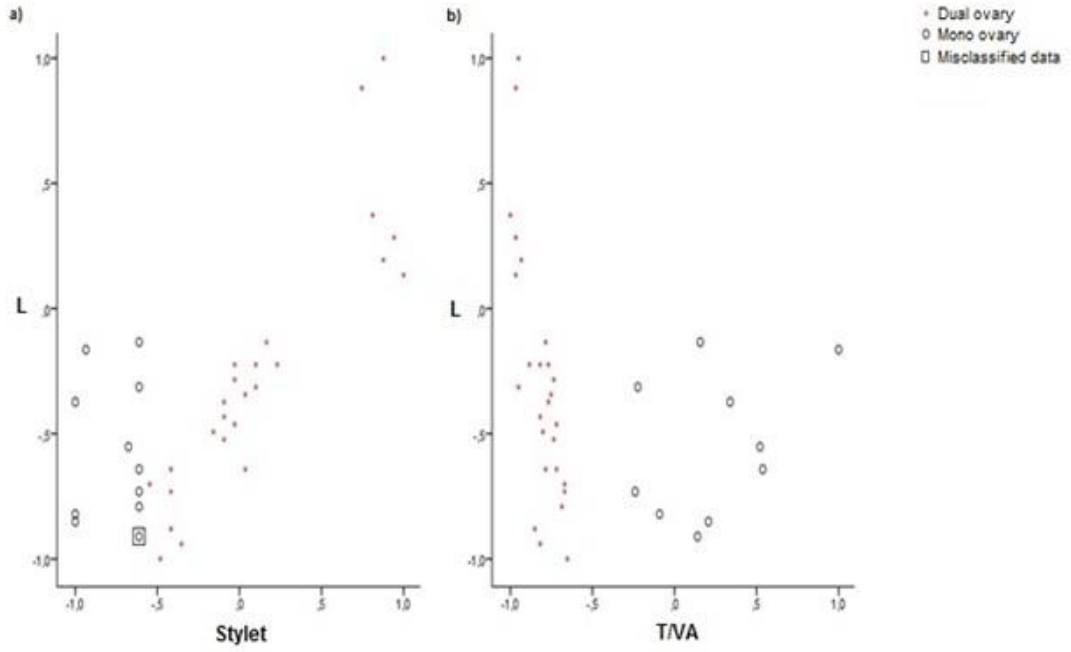

Figure 6. Plots show distribution of a) L versus Stylet (Selected Nn:15) and b) L versus (T/VA) (Selected Nn:5) for data set using ANNs approach in 2017, July. The accuracy percentages were obtained as 97% for pairs of L versus Stylet and as 100% for pairs of L versus (T/VA) parameters, respectively.

The comparison of ANNs approach results with the results of the LDF method can be seen in the Tables 11. and 12.

Table 11. Comparison of the accuracy percentage values for data set according to LDF method and ANNs approach. criteria 1: L versus Stylet and criteria 2: L versus (T/VA) parameters in 2016, July.

Criterion	Method and approach	Accuracy (%)
1	LDF	92
	ANNs	94
2	LDF	96
	ANNs	100

Table 12. Comparison of the accuracy percentage values for data set according to LDF method and ANNs approach. criteria 1: L versus Stylet and criteria 2: L versus (T/VA) parameters in 2017, July.

Criterion	Method and approach	Accuracy (%)
1	LDF	91
	ANNs	97
2	LDF	97
	ANNs	100

Results and Discussion

The identification of the type of ovaries was carried out using LDF method and ANNs approach. In this study sixty-four (59%) of studied total 109 individuals were described as dual ovaries and 45 (41%) of them were described as mono ovaries for 2016, July. Further seventy-four (61%) of studied total 121 individuals were described as dual ovaries and 47 (39%) of them were described as mono ovaries for 2017, July, too. Ovary types of female PPNs obtained from quince cultivation areas in Sakarya Province were determined and then, some morphometric parameters of them were distinguished from each other. The results of the classification method between the types of the ovaries using LDF method for pairs of criteria: 1- L versus Stylet and 2- L versus (T/VA) were shown for 2016, July and 2017, July data sets in Table 1. and Table 2., respectively.

In the first criterion in Table 1., 59 dual ovaries were classified correctly and 5 dual ovaries were misclassified as mono ovaries. 41 mono ovaries were classified correctly and 4 mono ovaries were misclassified as dual ovaries. So we obtained that the accuracy percentage of the classification is as 92% for 2016, July data set by using LDF method. In the second criterion in Table 1., 64 dual ovaries were classified correctly. 41 mono ovaries were classified correctly and 4 mono ovaries were

misclassified as dual ovaries. So we obtained that the accuracy percentage of the classification is as 96% for 2016, July data set by using LDF method.

Further in the first criterion in Table 2., 67 dual ovaries were classified correctly and 7 dual ovaries were misclassified as mono ovaries. 43 mono ovaries were classified correctly and 4 mono ovaries were misclassified as dual ovaries. So we obtained that the accuracy percentage of the classification is as 91% for 2017, July data set by using LDF method. In the second criterion in Table 2., 74 dual ovaries were classified correctly. 43 mono ovaries were classified correctly and 4 mono ovaries were misclassified as dual ovaries. So we obtained that the accuracy percentage of the classification is as 97% for 2017, July data set by using LDF method.

So Figure 2. and Figure 3. were drawn as graphics using these numerical values for July, 2016 and July, 2017, respectively.

After we discriminated mono and dual ovary using LDF method, we applied ANNs approach for the same pairs of parameters. Firstly we had to decide for Nn, and then we created test and training data set for the two criteria in Table 3. and Table 4., respectively. The values of the accuracy percentage for ANNs approach were also given in Table 5. and Table 6., respectively. The accuracy percentage values changed between 88% and %100. We increased the values of the number of neurons by 5 between 5 and 25 as shown in Table 5. and Table 6., respectively. And then Nn versus the determination coefficient (R^2) per data sets for L versus Stylet and L versus (T/VA) were given in Table 7. and Table 8., respectively. R^2 values changed between 0.83 and 1 in that table. This situation indicated that BPNNs learning algorithm was successful for those parameters on that structure of the network topology. The comparison of R^2 values that were obtained using ANNs approach for pairs of parameters in this study area and the comparison of R^2 versus the number of neurons were not enough for deciding unaccompanied. Table 7. and Table 8. showed that this relationship was only a stopping criterion for stopping the training stage of the network topology. Nn was decided as 10 and 5 at the network architectures for pair of criteria: 1 (L versus Stylet) and 2 (L versus (T/VA)) for July, 2016, respectively. Further they were decided as 15 and 5 at the network architectures for pair of criteria: 1 (L versus Stylet), 2 (L versus (T/VA)) for July, 2017, respectively. Because the average accuracy percentage were the highest as 94% and 100% for the July, 2016 data, as 97% and 100% for the July, 2017 data for pair of criteria: 1 (L versus Stylet) and 2 (L versus (T/VA)) respectively (See Table 9. and Table 10.). Further L versus Stylet values of the accuracy percentage for LDF method and ANNs approach were shown for 2016, July data set and for 2017, July data set in Table 11. and Table 12., respectively. According to L versus Stylet the accuracy percentage values were obtained using LDF method and ANNs approach as 92% and 94% for July, 2016 data set, respectively. And then according to L versus (T/VA) the accuracy percentage values were obtained as 96% and 100% for July, 2016 data set. Further L versus Stylet the accuracy percentage values were obtained using LDF method and ANNs approach as 91% and 97% for July, 2017 data set, respectively. And then according to L versus (T/VA) the accuracy percentage values were obtained as 97% and 100% for July, 2017 data set. Values of pairs of the L versus Stylet and the L versus (T/VA) for ANNs approach were plotted in Figure 5. and Figure 6. for 2016, July and 2017, July, respectively, too.

LDF method was one of the most popular and successful techniques for classification different groups among the multidisciplinary sciences in the world. For example the accuracy percentage values were obtained for pairs of parameters for the earth sciences (the pair of Ratio versus logS parameters) as 98.6%, 93.8%, 97.7% and 95.8% for Gaziosmanpaşa, Çatalca, Gebze-Hereke, and Ömerli, respectively (Horasan et al., 2009). The accuracy percentages were obtained as 96.3 %, 89.3%, 100%, 100%, 96.5%, and 100 % for the earthquake stations KTUT, ESPY, BAYT, PZAR, GUMT, and BCA, respectively (Yılmaz et al., 2013).

Further lower accuracy percentage values (91.7%, 83.7% and 83.2%) were obtained using Seconder/Primer wave amplitude peak ratio, complexity and spectral ratio in Egypt than the other country values (Badawy et al., 2019). Further in this study the values of the number of neurons which were increased by 5 between 5 and 25 was given in Tables 5., 6., 7., 8., 9. and 10. Nn versus R^2 values per data sets were shown in Table 4a. and Table 4b. for pairs of criteria 1: L versus Stylet and criteria 2: L versus (T/VA) parameters in 2016, July and July, 2017, respectively. R^2 values changed between 0.83 and 1 in these tables, too. It means that BPNNs learning algorithm was successful for these parameters on that structure of the network topology in the area considered in this study.

When we compared the accuracy percentage values for two criteria (L versus Stylet and L versus (T/VA)), the pair of L versus (T/VA) had higher classification percentage values for both of July, 2016 data set and July, 2017 data set (94% and 97%, respectively and 100% for ANNs approach) than the pair of L versus Stylet in Table 9. and Table 10. And then when we compared the accuracy percentage values for two criteria (L versus Stylet and L versus (T/VA)), the pair of L versus (T/VA) had higher classification percentage values for both of July, 2016 data set and July, 2017 data set (92% and 96%, respectively and 91% and 97% for LDF method) than the pair of L versus Stylet in Table 11. and Table 12. Further when we compared the accuracy percentage values for two criteria (L versus Stylet and L versus (T/VA)), the pair of L versus (T/VA) had higher classification percentage values for ANNs approach for both of July, 2016 data set and July, 2017 data set (94% and 100%, respectively and 97% and 100% for ANNs approach) than the pair of L versus Stylet for LDF method in Table 11. and Table 12. Further misclassified data was near the function line of the discrimination area according to LDF method (Figures 2. and 3.) and the limit of the discrimination area according to ANNs approach (Figures 5. and 6.) between two different areas called as “the mono ovary” and “the dual ovary”. This is a new finding in this study according to these discrimination method and approach, too.

Further ANNs approach was one of the most popular and successful techniques for classification different groups at the multidisciplinary sciences in the world, too. Similar three methods of the ANNs approach were used to distinguish the natural and artificial seismic events in Istanbul and its vicinity (Yıldırım et al., 2011). They obtained the success of the models as 99% for feed forward back propagation neural networks (FFBPNN). Some researchers investigated data sets for Edirne and Manisa using BPNN Learning algorithm successful between absolutely 80-100%, too (Tan et al., 2021a, b; Tan, 2021). Suitable ANNs models were studied to determine using performance criterion such as mean determination coefficient (R^2) as above 99% and used the BPNN learning algorithm at the forest industry (Akyüz, 2019; Tan, 2021). For that reason the ANNs approach can be used as a good tool in industrial wood sales forecasts. Further three of the ANNs approaches are that Multi-layer perceptron (MLP) and evolutionary-based, genetic algorithm with neural network (GANN) and evolutionary product unit-based neural network (EPUNN) approaches were applied to predict LD_{50} value using *Tribolium confusum* Jacquelin du val (Coleoptera: Tenebrionidae) in the entomological research area, too (Altay and Özgen, 2021).

ANNs approach studies were emphasized that classification of nematodes very importantly. Nematological studies that were generally researched about the non-linear solutions or manipulation of the images of the *C. elegans* using the neural networks in the World, too (Ferrèe et al., 1996; Sundararaju et. al., 2002; Li et al., 2016; Monteiro et al., 2016; Akintayo et al 2018; Golhani et al., 2018; Aragon et al., 2019; Saberi et al., 2020).

Conclusions

In this study the human intelligence, the computer intelligence and the artificial intelligence

were compared with each other. In fact we compared the human intelligence, the computer intelligence and the artificial intelligence with each other using measured values, statistical program and the neural networks, respectively. The accuracy percentage values of the LDF method were as successful as results using ANNs approach. But ANNs approach was more successful than LDF method for the classification of mono and dual ovaries of females of PPNs. Hence, we concluded that the mono and dual ovaries were discriminated from each other very well in this study and it may be developed the taxonomical studies using LDF method and ANNs approach together at the nematology. Further this is the first study by using LDF method and ANNs approach together at the nematological studies in both of Turkey and the World. Further we suggest that different training algorithms could be investigated by using different pairs of parameters in ANNs approach in the nematology.

Acknowledgements

The authors would like to thank Prof. Dr. Gündüz Horasan, Academical Staff, Sakarya University, Engineering Faculty, Geophysical Engineering Department, Sakarya, Turkey, for her encouraging motivation during the preparation of this study.

Funding: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflict of interest disclosure: All authors declare that there is no conflict of interest among them in this study.

Author contributions: Ayşe Nur TAN, Ph.D. obtained the taxonomical results from the study fields, collecting soil samples, isolating, fixing, preparing, counting, calculating and measuring of some physical parameters of the nematodes and then diagnosing in the laboratory and then researching some scientific journals and writing of some captions of the manuscript on the computer. And then Aylin TAN, Ph.D. arranged the data sets normalizing all data set for the statistical analysis and the artificial neural networks and then researching some scientific journals and writing of some captions of the manuscript on the computer. Hilal SUSURLUK, Ph.D. controlled the foreign language and then arranged the design of this manuscript.

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