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Synthesis and Characterization of Mn_3O_4 Doped Modified Electrodes for Vanadium Redox Flow Batteries

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ABSTRACT

In the present study, Mn_3O_4 doped electrodes were synthesized to improve the cathode V (IV)/V (V) redox reaction of all vanadium flow batteries. Cathode electrocatalysts were produced with a two-step hydrothermal method. The crystal structure of the Mn_3O_4 doped composites and electrodes were analyzed by X-ray diffraction (XRD) and scanning electron microscopy (SEM) was used for morphological examination of the samples. Surface modification of the electrodes was confirmed by thermo gravimetric analysis (TGA) and functional groups on the electrode surface were determined by X-ray Photoelectron Spectroscopy (XPS). Electrochemical measurements of the electrodes were conducted with cyclic voltammetry (CV) technique. Mn_3O_4 directly loaded onto graphite felt and carbon paper and Mn_3O_4/Vulcan XC-72 nanocomposite increased the electrochemical catalytic activity of cathode V (IV) / V (V) redox reaction. Peak currents of Mn_3O_4/Vulcan XC-72 doped graphite felt and SGL 10AA electrodes are measured as 42.30 and 7.9 mA, respectively. Despite the low electrical conductivity of Mn_3O_4, the composites formed with Vulcan XC-72 improved vanadium flow battery cathode performance.

Anahtar Kelimeler:
Vanadyum redoks akış pili
Mn_3O_4/Vulcan XC-72
Yüzey modifikasyonu
Grafit keçe
Karbon kağıt

ÖZ

Bu çalışmada, oluşturulan Mn_3O_4 katkılı elektrotlar, vanadyum akış pilleri katot V(IV)/V(V) çifti için sentezlenmiştir. Katot elektrokatalizörleri iki aşamada hidrotermal yöntem kullanılarak sentezlendi. Elde edilen Mn_3O_4 katkılı kompozit ve elektrotların kristal yapısı X-ışını difraksiyonu (XRD), morfoloji incelemesi için ise taramalı elektron mikroskobu (SEM) kullanılmıştır. Yüzey modifikasyonu termo gravimetrik analiz (TGA) ile doğrulanmış olup yüzeydeki fonksiyonel gruplar X-ışını Fotoelektron Spektroskopisi ile tespit edilmiştir. Elektrotların elektrokimyasal ölçümleri çevrimsel voltametri (CV) kullnılarak yapılmıştır. İlk aşamada oluşturulan Mn_3O_4 /Vulcan XC-72 kompoziti ve ikinci aşamada grafit keçe ile karbon kağıt üzerine yüklenen Mn3O4 , katot V(IV)/V(V) çiftinin elektrokimyasal katalitik aktivitesini artırmıştır. Mn_3O_4 /Vulcan XC-72 katkılı grafit keçe ve SGL 10AA elektrotlarının çalışma akımları sırasıyla 42.30 ve 7.9 mA'dir. Mn_3O_4'ün düşük elektriksel iletkenliği olmasına rağmen Vulcan XC-72 ile oluşturulan kompozitler vanadyum akış pili katot performansını iyileştirmiştir.

1. Introduction

Renewable energy systems such as wind and solar systems are intermittent energy generating systems. In order for renewable energy sources to be sustainable and efficient to use, the energy produced must be stored and provided to the system when necessary. Energy storage systems (ESS) can store renewable energy in different forms and, if necessary, convert it back to electrical energy. When the energy storage system is in electrochemical form (e.g. batteries, fuel cells, flow batteries), energy can be stored efficiently, safe, and at a lower cost [1].

The use of redox flow batteries (RFB) that store energy in electrochemical form, in energy storage applications has become widespread in recent years [2]. As a result of the electrochemical reactions in the redox flow batteries, ions flow within the cell and electrons flow in the external circuit [3]. One major difference of flow batteries from secondary batteries such as Li-ion, Lead-Acid, Ni-Cd is that they do not store reactants or products in the cell, instead chemicals are stored in separate storage tanks. The energy capacity of the system increases with the amount of electrolyte (anolyte or catholyte) in the storage tanks. As the active electrode area increases, the current drawn from the cell increases. In addition, the voltage of the flow battery module can be increased with serial connection of the cells. Therefore, the ability to regulate power and energy capacities independently is one of the most important advantages of redox flow batteries.

Among redox flow batteries, vanadium redox flow battery (VRFB) is the most widely studied and developed cell type. As a result, VRFB flow batteries are commercially available and widely used worldwide. The VRFB was first studied by Maria Skyllas-Kazacos [4]. The cathode electrolytes (catholyte) contain V^{4+}/V^{5+} ions in H_2SO_4 solution, while the anode electrolyte (anolyte) consists of V^{3+}/V^{2+} ions in H_2SO_4 solution. The concentration, activity and stability of vanadium ions in electrolytes are critical for vanadium redox flow battery performance [5]. The energy density of a vanadium redox flow cell with an acidic electrolyte having a vanadium concentration of 2M is about 20-30 Wh/L. The low solubility of vanadium ions and cell voltage are the most important parameters affecting energy density [6]. When the flow battery is in discharge mode, V^{5+}/V^{4+} reduction reaction occurs on the cathode side while V^{2+}/V^{3+} oxidation reaction occurs on the anode side [7].

$$(1) \quad \textbf{Cathode: } VO^{2+} + H_2O \underset{\text{Discharge}}{\overset{\text{Charge}}{\rightleftharpoons}} VO_2^{+} + 2H^{+} + e^{-} \qquad E^{o}= 1.00V$$

$$(2) \quad \textbf{Anode: } V^{3+} + e^{-} \underset{\text{Discharge}}{\overset{\text{Charge}}{\rightleftharpoons}} V^{2+} \qquad E^{o}=-0.25V$$

$$(3) \quad \textbf{Cell: } VO^{2+} + H_2O + V^{3+} \underset{\text{Discharge}}{\overset{\text{Charge}}{\rightleftharpoons}} VO_2^{+} + 2H^{+} + V^{2+} \qquad E^{o}= 1.25V$$

Protons formed with the electrochemical reactions inside the electrodes are transferred from anode to cathode by means of proton conductive membrane to ensure charge balance in the cell. Carbon-based electrodes are generally used in a typical vanadium flow cell. Carbon electrodes are very advantageous in terms of proper surface area, low cost and anode-cathode stability[8]. Carbon paper, carbon cloth, graphite felt, and carbon fiber are the commonly used electrodes in flow battery systems. The precursor materials commonly used for the production of graphite felt fibers are polyacrylonitrile (PAN) or Rayon, affecting the physical and electrochemical properties of the graphite felt. Graphite felt obtained from PAN fibers shows better electrochemical properties as compared to Rayon based graphite felts [9]. Starting from the precursor material, graphite felt is produced by polymerization, oxidation, carbonization and graphitization processes respectively. In addition, graphite felt has high electroactive surface area, high electrical conductivity (370.37 S/m), good mechanical and chemical stability. On the other hand, the hydrophobic nature of the graphite felt limits performance in vanadium redox flow batteries [10,11]. Among the mentioned electrodes, to improve the weak electrochemical properties of the graphite felt electrode and to enhance the performance of the vanadium redox flow battery, surface modification should be carried out. Some methods used for surface modification are acid treatments [12], thermal treatments [13], thermo-chemical treatment, and hydroxylation [14]. As a result of the acid treatment of graphite felt with sulphuric acid, W. Zang and his coworkers reported that the oxygen-containing functional groups on the graphite felt surface increased. This increase in the surface of oxygen-containing functional groups increased the wettability of the graphite felt and reduced the resistance during charge transfer [15]. In general, precious metals such as Pt, Ru, Pd and Ir are used as electrocatalysts in Vanadium Redox Flow Batteries [16-18]. These precious metals significantly improve the performance of the VRFB, but the cost of these catalysts is quite high. In VRFB systems, instead of precious metals, low-cost metal oxide catalysts such as WO_3 [19] and Mn_3O_4 (referans) can be used. Due to its low electrical conductivity, Mn_3O_4 reduces the performance of vanadium redox flow battery by creating resistance during charge transfer. The performance of the vanadium redox flow battery can be increased when Mn_3O_4 is used as a composite with a porous material having good electrical conductivity. It is possible to obtain a catalyst with low cost, high conductivity and high electrochemical catalytic activity by providing homogeneous nano scale distribution of metal oxide catalyst in graphite felt electrode [20-22].

In this study, Mn_3O_4 metal oxide was used as catalyst. In order to improve the electrode kinetics, the low electrical conductivity of Mn_3O_4 was developed by impregnating onto the carbon black and the Mn_3O_4/Vulcan XC-72 composite was formed. To enhance the performance of the graphite felt electrode, surface modification was made using acid and thermal treatment methods. The produced Mn_3O_4/Vulcan XC-72 composite was placed in the graphite felt pores with the hydrothermal synthesis technique. X-ray diffraction (XRD), X-ray photo electron spectroscopy (XPS) and Scanning Electron Microscopy (SEM) techniques were used in the surface and structural analysis of the graphite felt obtained after surface modification with Mn_3O_4/Vulcan XC-72. Electrochemical measurements were performed by cyclic voltammetry tests.

2. Material and Method

2.1 Preparation of electrocatalyst

This study was carried out in two steps. In the first step, Mn_3O_4/Vulcan XC-72 electrocatalyst was prepared. Vulcan XC-72 (Cabot®) was treated with hydrogen peroxide (50%, Tekkim®) for surface activation at 120°C for 5h. The sample was washed with deionized water until the pH was stabilized and dried in a vacuum oven at 60°C overnight. Surface modified Vulcan XC-72 carbon was mixed in 1M $Mn(Ac)_2.4H_2O$ (99%, Sigma-Aldrich®) for 1h and after that sample was ultrasonicated for 3h. The graphite felt (3mm PAN based, Hi-Tech Carbon®) was cut to 3cm x 3cm. During the course of hydrothermal reaction, mixture of graphite felt electrode and Mn_3O_4/Vulcan XC-72 suspension was treated in a teflon coated autoclave for 12h at 200ºC. The autoclave was cooled to room temperature and the graphite felt electrode was washed with deionized water until pH was stabilized. The resulting graphite felt-based electrode was dried in a vacuum oven at 25ºC overnight. To compare Mn_3O_4 /Vulcan XC-72 performance, only Mn_3O_4 catalyst was loaded on the graphite felt by hydrothermal method. The Mn_3O_4/Vulcan XC-72 electrocatalyst was loaded on a carbon paper (10AA GDL, SGL Group®) by hydrothermal method to compare the graphite felt with carbon paper as an alternative electrode.

2.2 Characterization

Surface morphology analyses of the samples were performed using scanning electron microscopy (SEM) with an acceleration voltage of 10kV (JEOL, JSM-7001F). The X-Ray diffraction (RIGAKU, SMARTLAB) analyses of the samples were conducted using the Cu-Kα1 source with a screening angle of 2-90º, and scanning speed of 2º min^{-1}. Thermogravimetric analysis (TGA, BRUKER, TENSOR 27) was used to determine the thermal history of the electrodes. X-ray photoelectron spectroscopy (XPS) (PHI 5000 VersaProbe) was used to observe the functional groups on the surface of the electrodes.

2.3 Electrochemical measurements

Cyclic voltammetry (CV) analysis was performed with a scan rate of 5 mVs^{-1} in 0-1.5V range using 0.5M VO_SO_4 (99%, Sigma-Aldrich®) and 2M H_2SO_4 (95-97%, Merck®) solution. All electrochemical analyzes were performed under an inert atmosphere using a Potentiostat-Galvanostat (Stath, IVIUM) device and a standard three-electrode electrochemical cell. Ag/AgCl (3M NaCl) was used as the reference electrode and platinum wire was used as the counter electrode.

3. Result and Discussion

Fig.1 shows XRD patterns of graphite felt and carbon paper after surface modification of graphite felt and carbon paper with Mn_3O_4/Vulcan XC-72.

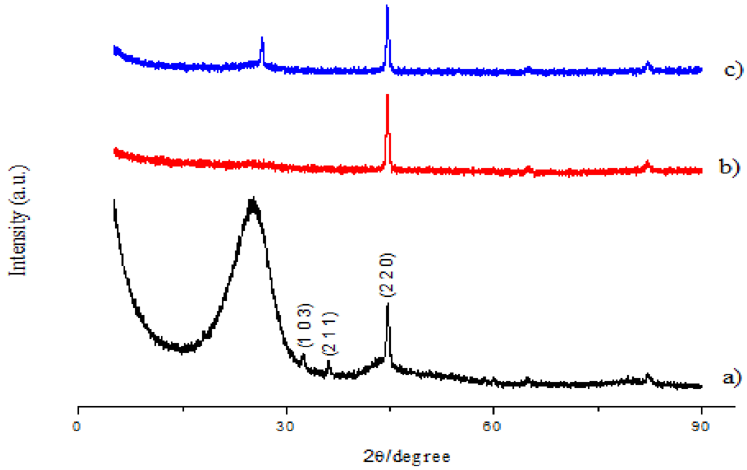
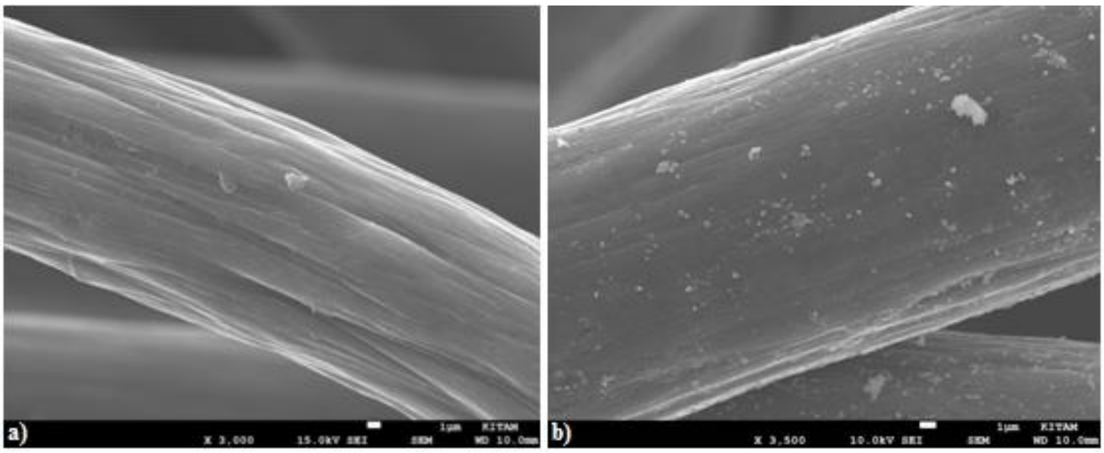


Figure 1. XRD paterns of electrodes **a)** Mn_3O_4/GF, **b)** Mn_3O_4+Vulcan XC-72/ GF, **c)** Mn_3O_4+Vulcan XC-72/10AA

In XRD analysis, a typical peak (002) was observed at 26.4º (JCPDS card files, no. 41-1487), which is generally attributed as the characteristic peak of the graphite felt and carbon paper. Observed diffraction peak positions and corresponding crystal planes of the Mn_3O_4 crystals on graphite felt and carbon paper are detected at 32.4º (1 0 3), 36.1º (2 1 1) and 44.5º (2 2 0) respectively. The resulting relatively low density diffraction peaks are in accordance with the reported values of Mn_3O_4. Crystallite size is related to the broadening of a peak in the diffraction pattern. The crystallite size of the Mn_3O_4 particle prepared by hydrothermal method was calculated using Scherrer formula and the average crystal size was found to be approximately 21 nm, which is in agreement with the reported data (Fig. 2c) in SEM micrograph [23].



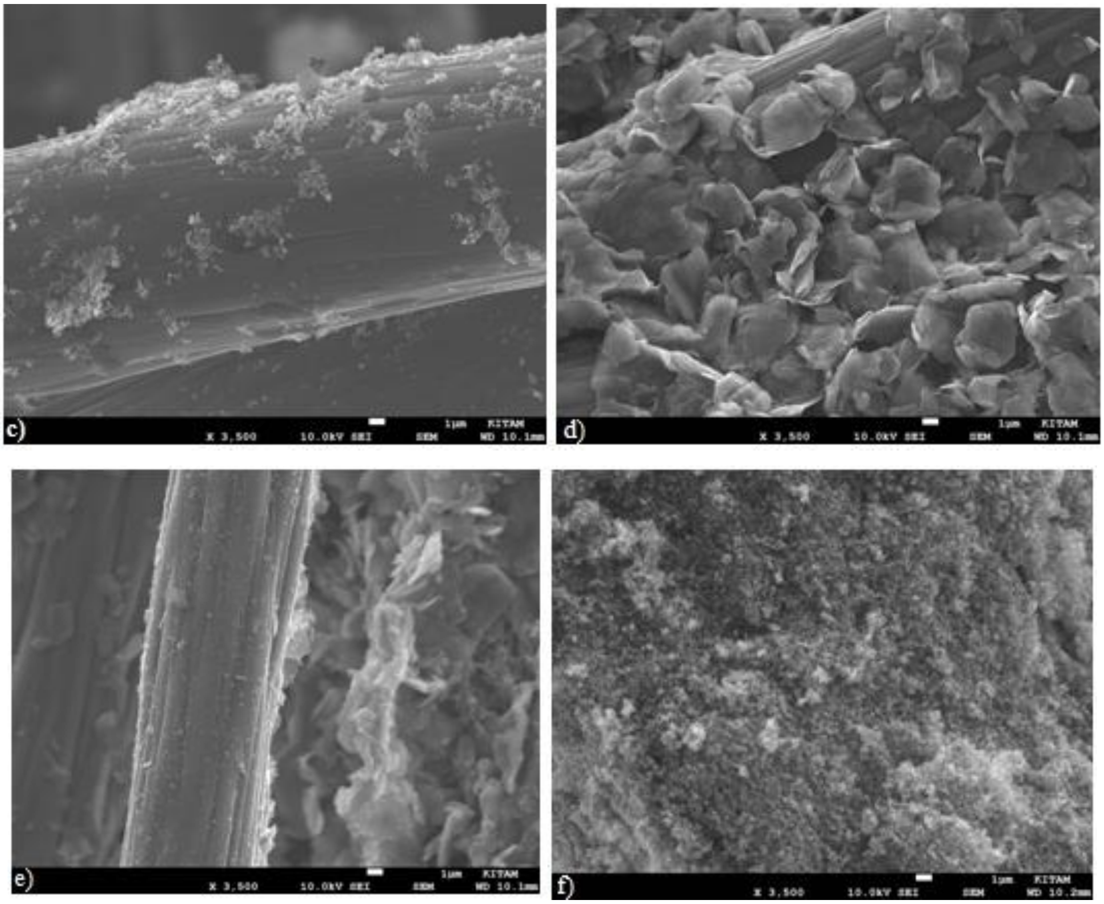


Figure 2. SEM images of electrodes **a)** pristine GF, **b)** Mn_3O_4 based GF, **c)** Mn_3O_4/Vulcan XC-72 based GF, **d)** pristine SGL 10AA**, e)** Mn_3O_4/Vulcan XC-72 based SGL 10AA, **f)** Mn_3O_4/Vulcan XC-72

The micrographs from the SEM analysis shown in Fig 2. exhibits the surface morphology of the Mn_3O_4 modified graphite felt electrode. When the SEM images are examined, it can be concluded that the Mn_3O_4 particles are successfully loaded onto the graphite felt.

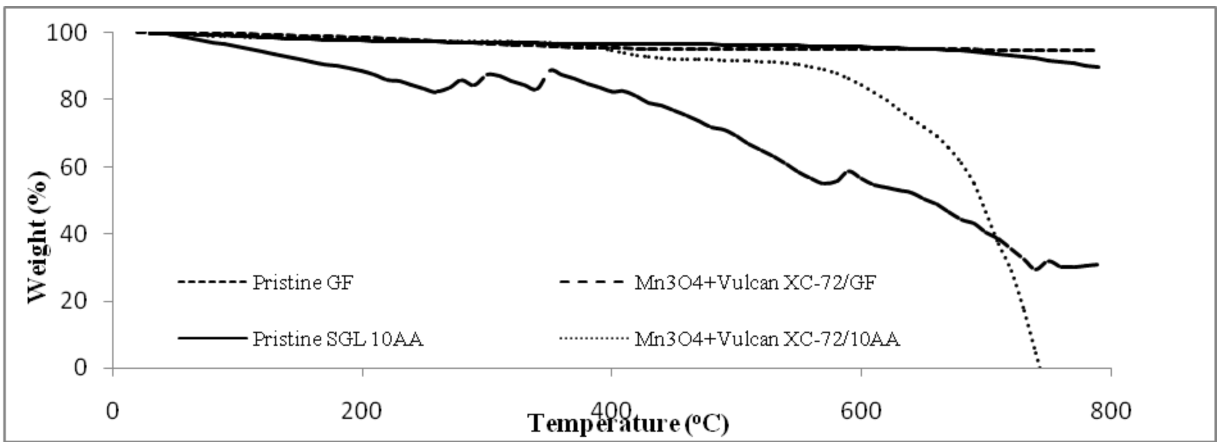


Figure 3. TGA curves of electrodes under nitrogen

The results of thermogravimetric analysis for graphite felt and carbon paper under nitrogen atmosphere before and after modification are shown in Fig.3. The mass loss of graphite felt and carbon paper after surface modification increased significantly. After the surface modification of electrodes, functional groups containing oxygen were possibly increased on the surface and, accordingly, these functional groups and small amounts of water on the surface were released during TGA analysis, resulting in an increase in mass loss in the electrodes. The increase in these functional groups increases the electroactive area on the surface, resulting in improved electrode kinetics in the vanadium redox flow batteries. TGA analyses showed that the pristine graphite felt and carbon paper remained thermally stable to the temperatures up to 800°C. 70% and 95% mass loss were observed on modified graphite felt and carbon paper, respectively. One may conclude that this mass loss supports the presence of functional groups containing oxygen on the electrode surface as a result of modification.

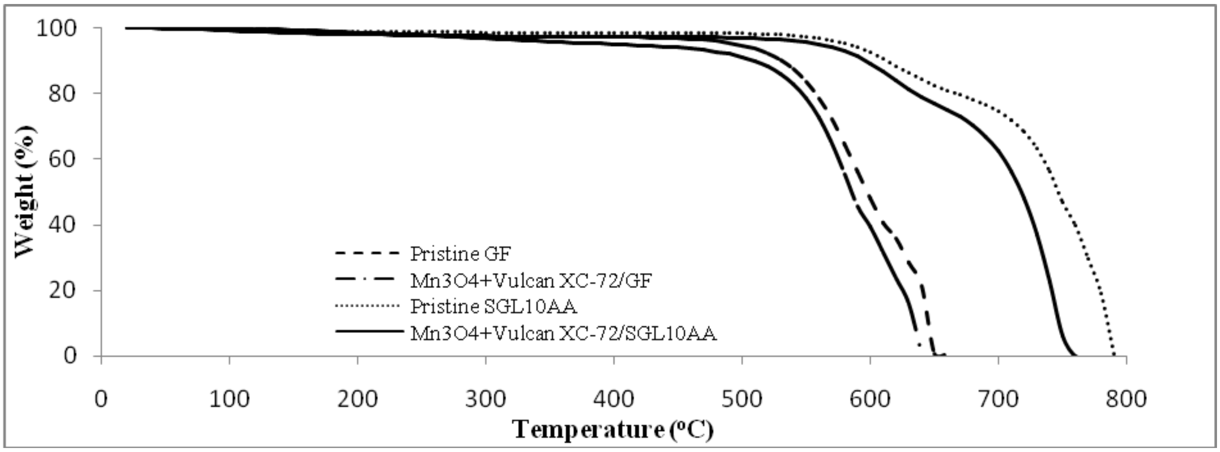
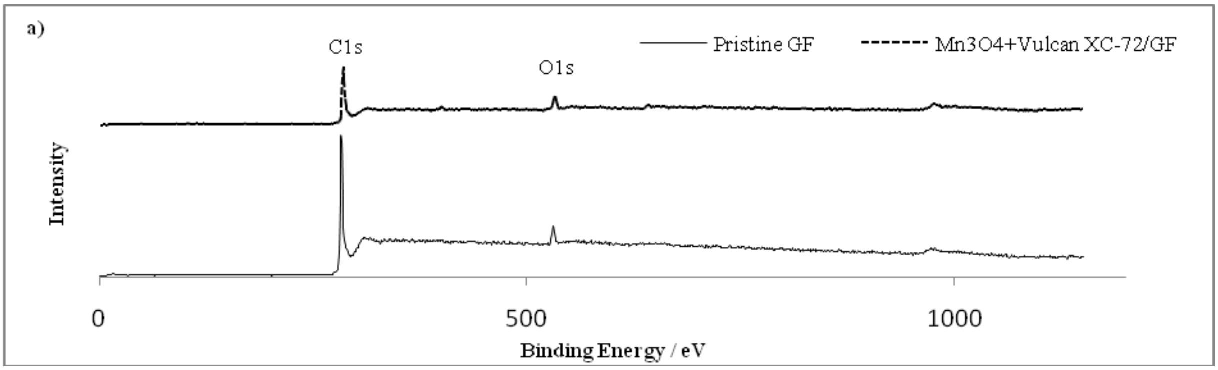


Figure 4. TGA curves of electrodes under air

The results of TGA analysis for graphite felt and carbon paper under oxygen atmosphere before and after modification are given in Fig. 4. Most of the mass loss is due to the combustion reaction of graphite felt and carbon paper in approximately 500 °C.

Fig. 5 shows the XPS surveys before and after graphite felt and GDL 10 AA are doped with Mn_3O_4/Vulcan XC-72.



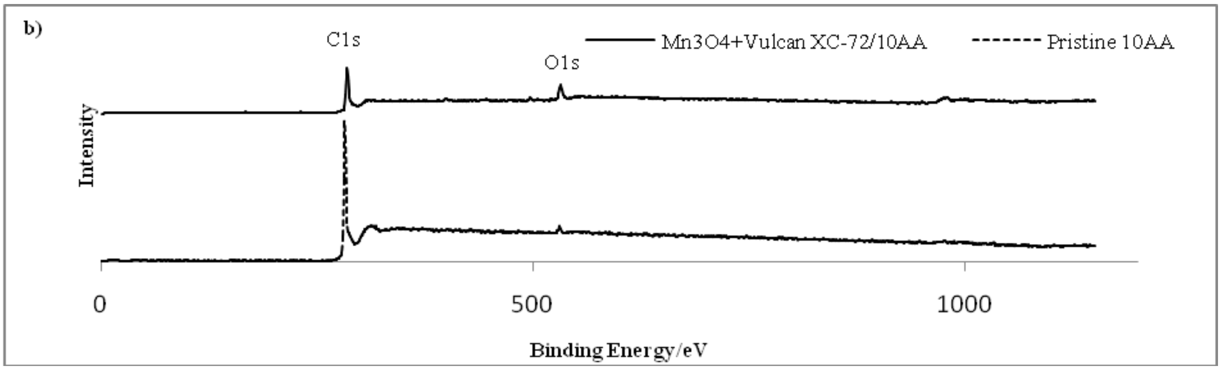
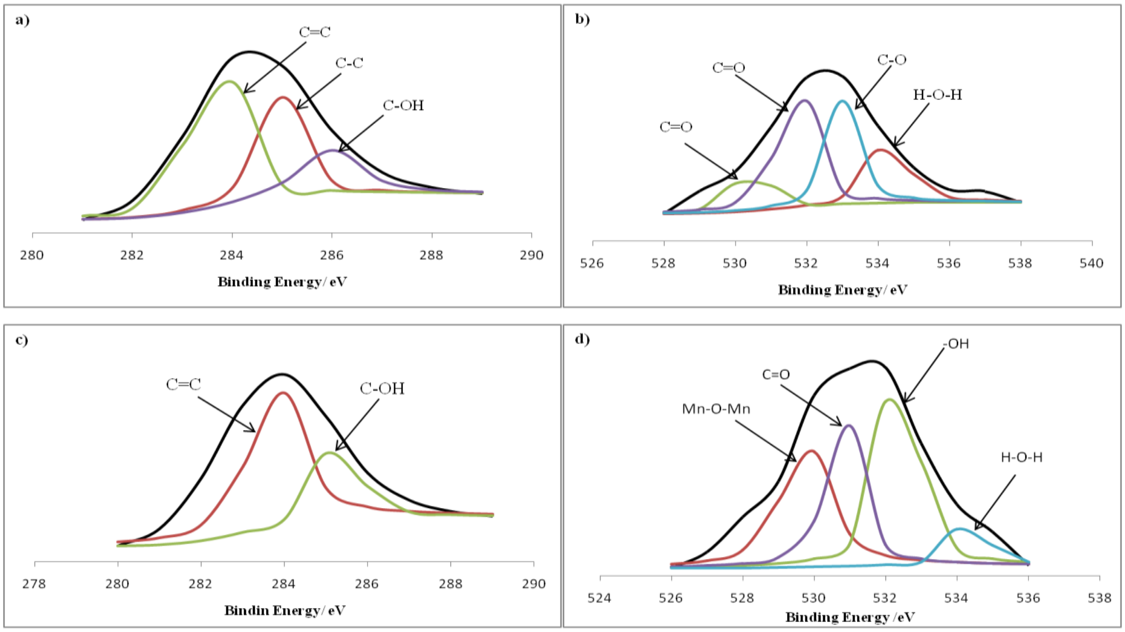


Figure 5. XPS surveys of 10AA and graphite felt

In addition, XPS data were used to fit a curve to get C1s and O1s spectra of all electrodes, which are presented in Fig. 6. Spectra are calibrated according to the binding energy of the carbon at 284.7 eV.



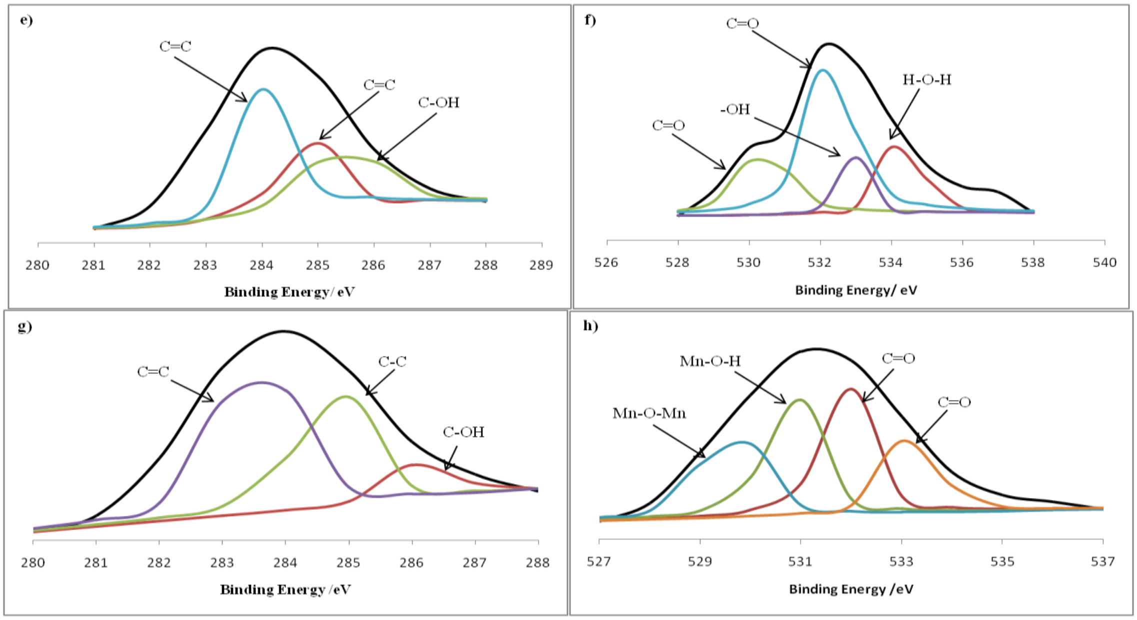


Figure 6. XPS curve-fit C1s and O1s spectra of electrodes, pristine GF (a and b) Mn_3O_4/Vulcan XC-72 based GF (c and d), pristine SGL 10AA (e and f), Mn_3O_4/Vulcan XC-72 based SGL 10AA (g and h)

The surface functional group contents of the samples are listed in Table 1 and Table 2. In Table 1, The O/C ratios of graphite felt and carbon paper were compared before and after modification. The O/C ratio was found as 0.15 and 0.17 for graphite felt and carbon paper, respectively, after modification. This result confirms the increase in functional groups containing oxygen on the electrode surface.

Table 1. XPS C1s and O1s spectra data

Sample	C1s (%)	O1s (%)	O/C Ratio
Pristine GF	95.30	4.70	0.05
Mn_3O_4+Vulcan XC-72/GF	87.25	12.75	0.15
Pristine SGL 10AA	98.60	2.40	0.02
Mn_3O_4+Vulcan XC-72/SGL 10AA	85.50	14.50	0.17

Table 2. Data of XPS functional groups

	C1s			O1s					
Sample	**C=C**	**C-C**	**C-OH**	**C-O**	**C=O**	**-OH**	**H-O-H**	**Mn-O-Mn**	**Mn-O-H**
Pristine GF	55.20	27.00	17.80	26,70	53		20.03		
Mn_3O_4+Vulcan XC-72/GF	49.92		25.63		23.68	36.84	8.60	27.65	
Pristine SGL 10AA	31.92	25.20	23.75		65.78	9.08	19.84		
Mn_3O_4+Vulcan XC-72/SGL 10AA	47.94	31.45	9.01		45.02			25.04	27.80

As can be seen from Fig.6, C1s peak positions and binding energies were attributed to C-C (284.7, 289.9 eV), C=C (283.75, 284 eV), C-OH (285.9, 286.25 eV) functional groups [24]. When the O1s peak positions and binding energies were examined, C-O (533 eV), C=O (530, 530.8, 531.7, 532.3 eV), -OH (532.88 eV), H-O-H (534.3, 534.4, 535 eV), Mn-O-Mn (529.7 eV), Mn-O-H (530.76 eV) functional groups were detected [25].

Fig. 7 and Fig. 8 show the cyclic voltammograms of graphite felt and SGL 10AA carbon paper electrode before and after surface modification.

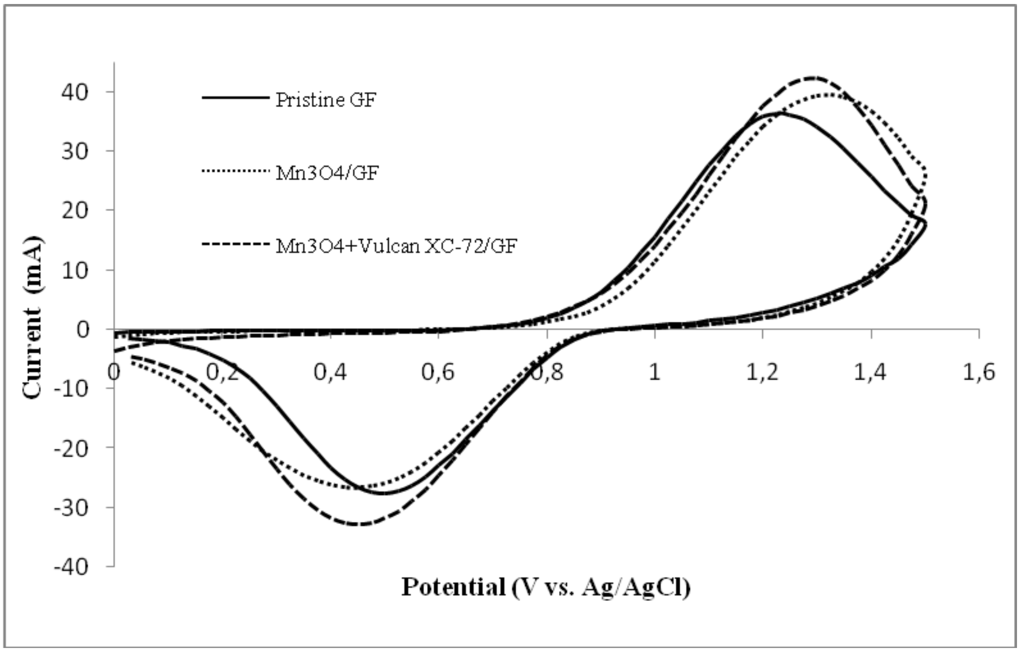


Figure 7. Cyclic voltammograms of graphite felt a scan rate of 5mVs^{-1} in 0,5 M $VOSO_4$+ 0,5 M H_2SO_4 solution

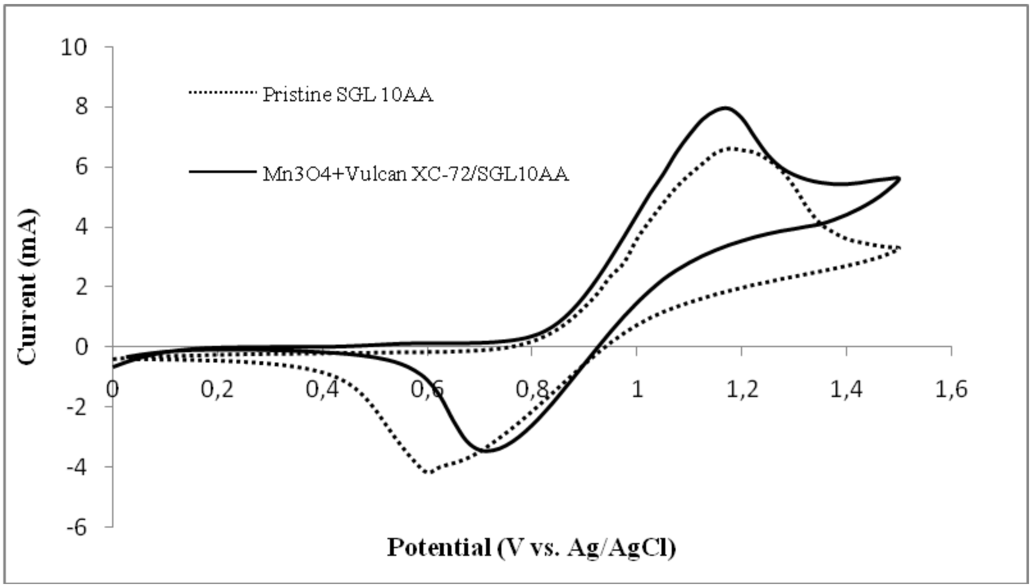


Figure 8. Cyclic voltammograms of SGL 10AA a scan rate of 5mVs^{-1} in 0,5 M $VOSO_4$+ 0,5 M H_2SO_4 solution

The data obtained from cyclic voltammograms are presented in Table 3 and Table 4.

Table 3. Parameters obtained from CV curves for graphite felt electrode

Electrode sample	I_{Pa} (mA)	E_{Pa} (V)	I_{Pc} (mA)	E_{Pc} (V)	I_{Pa}/I_{Pc}
Pristine GF	36.40	1.22	27.51	0.50	1.32
Mn_3O_4/GF	39.55	1.32	26.60	0.45	1.48
Mn_3O_4+Vulcan XC-72/GF	42.30	1.31	32.77	0.45	1.29

Table 4. Parameters obtained from CV curves for SGL 10AA

Electrode sample	I_{Pa} (mA)	E_{Pa} (V)	I_{Pc} (mA)	E_{Pc} (V)	I_{Pa}/I_{Pc}
Pristine Carbon Paper	6.61	1.17	4.15	0.60	1.59
Mn_3O_4+Vulcan XC-72/Carbon Paper	7.97	1.17	3.45	0.72	2.31

Cyclic voltammograms have good characteristic symmetry. The high performance of electrodes containing Mn_3O_4+Vulcan XC-72 is due to the active Mn_3O_4 electrocatalyst. When Mn_3O_4/GF and Mn_3O_4+Vulcan XC-72/GF were compared, it was determined that the best performance was obtained with Mn_3O_4+Vulcan XC-72 based graphite felt. This high performance is probably resulted from the homogenous distribution of the electrocatalyst by impregnating the Mn_3O_4 electrocatalyst with Vulcan XC-72 into the graphite felt. Activation of Vulcan XC-72 carbon black caused Mn_3O_4 crystals to retain in a more stable form on the carbon surface. Electrocatalyst impregnation with surface modification facilitates the transfer of electrons in the graphite felt to enable oxidation at the cathode. In addition, by increasing the wettability of the graphite felt, the transfer of vanadium ions was facilitated, which increased the V (IV)/V (V) cathode electrocatalytic performance.

4. Conclusions

In this study, Mn_3O_4 / Vulcan XC-72 composite was synthesized by using hydrothermal method. The performance of the synthesized composite was examined for V (IV)/V (V) redox reaction. The XRD pattern shows that Mn_3O_4 particles were successfully dpoed into the electrode structure. XPS results indicate the presence of functional groups on the electrode surface and confirmed the increase in oxygen containing functional groups over the surface. Mass loss seen in TGA results was attributed to functional groups containing oxygen. When the catalytic performance of the electrodes was examined, electrodes prepared with Mn_3O_4/Vulcan XC-72 composite exhibited higher performance than pristine electrodes. The Mn_3O_4/Vulcan XC-72 composite is a promising cathode catalyst for vanadium redox flow battery.

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The Investigation of the Change in Concentrations of Some Heavy Metals in Seeds, Leaves, and Branches because of Traffic Density: a Case Study of *Acer platanoides* L.

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ABSTRACT

Heavy metals are pollutants that are released into the atmosphere usually through industrial or traffic sources. Monitoring the heavy metal pollution is of great importance because, in addition to being carcinogenic in terms of their effects on human health, some are toxic even in low concentrations. They also tend to bioaccumulate. Using the plants as biomonitors, it is vital to determine the appropriate and effective plant species and the organelles of the plants to monitor each heavy metal type for the most accurate calculations. In this study, changes of the concentrations of Ba, Al, B, Ca, Fe, K, Mg and Mn elements in *Acer platanoides* were determined depending on the organelle and traffic density. As a result of the study found out that the elements subject to the study differed significantly at least at a 95% confidence level on the organelle basis of the elements other than Ba and Mn. When the changes of the elements depending on the traffic density were separately evaluated, it was determined that Ba and Fe elements increased depending on the traffic density in all organs.

Anahtar Kelimeler:
Acer platanoides,
Biomonitor,
Ağır metal,
Organ,
Trafik.

ÖZ

Ağır metaller, genellikle endüstriyel veya trafik kaynakları yoluyla atmosfere salınan kirleticilerdir. Ağır metal kirliliğinin izlenmesi büyük önem taşımaktadır, çünkü insan sağlığı üzerindeki etkileri açısından kanserojen olmasının yanı sıra, bazıları düşük konsantrasyonlarda bile toksiktir. Ayrıca biyolojik olarak birikme eğilimindedirler. Bitkileri biyo-monitörler olarak kullanmak, her bir ağır metal tipini en doğru hesaplamalar için izlemek üzere uygun ve etkili bitki türlerini ve bitkilerin organellerini belirlemek çok önemlidir. Bu çalışmada *Acer platanoides* lerinde Ba, Al, B, Ca, Fe, K, Mg ve Mn elementlerinin konsantrasyonlarındaki değişiklikler organel ve trafik yoğunluğuna bağlı olarak belirlenmiştir. Çalışma sonucunda, araştırmaya konu olan elementlerin Ba ve Mn dışındaki elementlerin organel bazında en az % 95 güven düzeyinde önemli ölçüde farklılık gösterdiği tespit edilmiştir. Trafik yoğunluğuna bağlı elementlerin değişimleri ayrı ayrı değerlendirildiğinde, tüm organlardaki trafik yoğunluğuna bağlı olarak Ba ve Fe elementlerinin arttığı belirlenmiştir.

1. Introduction

Today, the most important problems of the world in general are the problems related to population growth. While the world population was only 717 million in 1750, it exceeded 6 billion in 2000 and is estimated to exceed 8 billion in 2025 [1]. In addition to the increase in the world population, the increasing number of the populations living in urban centers has created many challenges. This process ruins nature, pollutes the air, water and soil, and the destroys the ecological balance [2-12]. Air pollution is one of the most important problems of today [10-12]. In fact, it is stated that approximately 6.5 million people die every year from to air pollution related causes. Weather many considered quite clean by country Turkey on air pollution, even in 2016 it is stated that due to the 29 thousand people lost their lives [13].

Metals such as Hg, Cd, As and Pb have serious toxic effects on organisms even at low levels [14-16]. Although micronutrients such as Mn, Zn, Cr, Cu, Fe and Ni are required for living organisms, including plants, they can also produce harmful effects at high concentrations. Studies show that almost all metals are toxic when taken over a certain amount [17-19]. Since heavy metals are so important to human health, the determination and monitoring of the concentration of heavy metals in the air is extremely important to determine risk zones and risk levels [20-26].

The change of heavy metal pollution in the atmosphere can be determined by direct and indirect methods. However, bioindicators are one of the most effective methods for detecting air pollution. In addition to being cheap and easy, this method can provide information on the effect of heavy metal concentration on the ecosystem [27,28].

Landscaping plants most exposed to air pollution are the best indicators of this pollution. The accumulation of heavy metal pollution caused by fossil fuels in various organs, especially in the regions where traffic is heavy, shows the progress of heavy metal concentration in air over time [5, 15, 21, 24]. Therefore, instead of direct detection of heavy metal pollution, bioindicators or biomonitorers are often used as indicators of pollution [21, 29-31]. In this study, it was aimed to determine the change of some heavy metal concentrations in *Acer platanoides* leaf seeds and branches grown in Kastamonu city center as in many regions of our country depending on plant organ, washing status and traffic density.

2. Materials and Methods

2.1 Materials

The study was conducted on samples collected from the city center of Kastamonu. Kastamonu city center was established in a valley as a general view, and the has densest traffic during the day. Samples were collected from regions where traffic density is high, lower and almost no traffic with no vehicles in a radius of at least 50 m.

Kastamonu city center is a region where 2 lanes in each direction pass through a 4 lane highway. The areas where the traffic is less dense are the areas outside the city center where the traffic is flowing along the main road. Taşköprü and İnebolu routes were determined as the areas with less traffic. There is a two-lane road in this region, the traffic is very smooth and the traffic density is quite low compared to the town center. In the absence of traffic, Kastamonu University campus area was selected and the points where no motorway was located at least 50 m near the campus area were selected and samples were collected from these areas. Leaf, seed and branch samples were collected from the same branch towards the end of the 2018 vegetation season, in late August bagged, labeled and takento the laboratory**.**

2.2 Methods

Leaves, branches and seeds in the laboratory were separated and grouped. Then, the branches were broken and crushed to dry more easily, and the seeds were crushed. The seeds were crushed with marble pieces and no metal tools were used. The prepared samples were placed in glass petri dishes and re-labeled. The samples prepared in this way were left to dry for 15 days and the laboratory was ventilated daily. The air-dry samples were put into the oven at 45oC for one week to allow them to dry completely.

In the next step, the plant samples were milled and pulverized and 0.5 g weighed into tubes designed for microwave. 10 mL of 65% HNO_3 was added to the samples. During these processes, fume was worked in. The prepared samples were then burned for 20 minutes at 280 PSI and 180 ºC in the microwave. The tubes were removed from the microwave after the completion of the treatments and allowed to cool. Deionized water was added to the cooled samples to 50 ml. The prepared samples were read on the ICP-OES device at appropriate wavelengths after filtration through filter paper.

The data obtained were analysed with the help of SPSS, Variance analysis and Duncon test was done in order determine to the means with statistical differences of at least a 95% confidence level and then to obtain homogeneous groups.

3. Ressults

3.1. Variation of heavy metal concentrations on organ basis

The variation of heavy metal concentrations on the basis of organs presented in Table 1.

Table 1. Variation of heavy metal concentrations on organ basis

	Leaf	Seed	Branch	F	Error
Ba	18,367	11,533	15,122	1,800	0,187
Al	158,22 c	113,00 b	31,22 a	58,114	0,000
B	110,11 b	42,44 a	48,44 a	8,391	0,002
Ca	2694,78 b	1899,89 a	3831,89 c	13,104	0,000
Fe	411,00 b	326,00 b	133,44 a	11,812	0,000
K	9418,67 b	15303,00 c	5566,56 a	44,058	0,000
Mg	7420,78 b	4453,56 a	8816,78 c	27,001	0,000
Mn	68,00	43,78	71,56	1,461	0,252

According to Table 1 was observed that only the change of Ba and Mn concentrations on organ basis was not statistically significant at least a 95% confidence level, the change of B concentration on organ basis was statistically significant at 99% and other elements at 99.9% confidence level. The highest concentrations were found in leaves in Al, B and Fe, in branches in Ca and Mg and in seeds in K.

3.2. Variation of heavy metal concentrations in leaves due to traffic density

Variance anlysis and Duncon test results for the variation of heavy metal concentrations due to traffic density was given in Table 2.

Table 2. Variation of heavy metal concentrations in leaves due to traffic density

	No traffic	Low Traffic	Dense Traffic	F Value	Error
Ba	6,400 a	22,267 b	26,433 b	10,011	0,012
Al	137,00 b	124,67 a	213,00 c	3252,053	0,000
B	192,67 c	75,67 b	62,00 a	69636,5	0,000
Ca	3461,67 b	846,00 a	3776,67 c	12485,948	0,000
Fe	329,33 a	324,00 a	579,67 b	8116,521	0,000
K	4791,00 a	12675,00 c	10790,00 b	37389,221	0,000
Mg	8910,67 c	4454,00 a	8897,67 b	3,57E+07	0,000
Mn	103,67 c	53,00 b	47,33 a	12988,5	0,000

As seen in Table 2, the change in traffic density of all elements in leaf samples is statistically significant at least a 95% confidence level. According to the average values and Duncan test results, Ba and Fe concentrations increase with traffic density and the change of concentrations of other elements was not related to traffic density.

3.3. Variation of heavy metal concentrations in seeds due to traffic density

Variance anlysis and Duncon test results for the variation of heavy metal concentrations due to traffic density was given in Table 3.

Table 3. Changes in heavy metal concentrations depending on traffic density in seeds

	No traffic	Low Traffic	Dense Traffic	F Value	Error
Ba	8,900 a	11,967 b	13,733 c	3229,800	0,000
Al	108,00 a	111,67 b	119,33 c	82,091	0,000
B	61,67 c	30,67 a	35,00 b	3804,500	0,000
Ca	1887,33 a	1913,00 c	1899,33 b	2226,500	0,000
Fe	218,00 a	222,00 b	538,00 c	33712,000	0,000
K	13700,67 a	15282,33 b	16926,00 c	1539,500	0,000
Mg	4454,67 b	4453,33 a	4452,67 a	9,333	0,014
Mn	110,00 c	4,00 a	17,33 b	90004,000	0,000

As considered Table 3 the change of all elements depending on traffic density was statistically significant at least a 95% confidence level in seed samples as in leaf samples. According to the average values and Duncan test results, the concentrations of Ba, Al, K and Fe increase with the traffic density and the change of the concentration of other elements was not related to the traffic density.

3.4. Variation of heavy metal concentrations in branches due to traffic density

Variance anlysis and Duncon test results for the variation of heavy metal concentrations due to traffic density was given in Table 4.

Table 4. Variation of heavy metal concentrations in branches due to traffic density

	No traffic	Low Traffic	Dense Traffic	F	Error
Ba	8,200 a	11,767 b	25,400 c	22249,300	0,000
Al	28,33 b	48,00 c	17,33 a	3258,500	0,000
B	41,00 b	75,33 c	29,00 a	15613,000	0,000
Ca	3818,67 b	3804,00 a	3873,00 c	3567,700	0,000
Fe	56,00 a	126,67 b	217,67 c	35469,800	0,000
K	5682,00 b	5788,67 c	5229,00 a	467,391	0,000
Mg	8664,00 a	8926,33 c	8860,00 b	1560,115	0,000
Mn	109,00 c	69,67 b	36,00 a	9010,750	0,000

When Table 4 was examined, the change of all elements depending on traffic density was statistically significant at least a 95% confidence level in branch samples as in leaf and seed samples.

According to the average values and Duncan test results, Ba and Fe concentrations increased with traffic density and the change of concentrations of other elements was not related to traffic density.

4. Discussion

As a result of the study, it was determined that the concentrations of elements other than Ba and Mn elements on organ basis were statistically significant at least a 95% confidence level. This has been demonstrated in numerous studies to date. Mossi [32] stated that the concentrations of Cu, Ni, Pb, Cd and Ca in the plants subject to the study were higher than those in the leaves, whereas Mn concentration was higher in the leaves than the branches. Sevik et al. [29] stated that the concentrations of heavy metals in organs were different based on species, for example, the highest Ni concentration was obtained in ornamental plum in seed, horse chestnut, linden and ash, and there was no statistically significant difference between organs in maple.

In studies related to heavy metals, the variation of heavy metal concentrations depending on the organ is often the subject of studies. Mossi [32] leaf and branch, Turkyilmaz et al., [23] bark and wood, Sevik et al., [30] leaf, seed and branch, Elfantazi et al., [33,34] leaf and branch, Ozel [35] leaf, branch and fruit, Pınar [36] leaf, branch and seed, Akarsu [37] determined the differences between the inner shell, outer shell and wood organelles. In these studies, it has been shown that heavy metal concentrations variedy significantly on an organelle basis.

The exchange of heavy metals in relation to the organ is a complex and not yet fully understood mechanism that is shaped by the structure of the plant and organelle as well as the structure of the heavy metal, the environmental conditions and the mutual interaction between them, and the information on this issue is limited [14, 19, 38]. Heavy metals can enter the plant via root or leaf uptake, but it is very difficult to distinguish whether heavy metals in the plant's internal tissues are taken from the soil or atmosphere because both uptake pathways can work simultaneously [21, 39-41]. Therefore, it is difficult to determine the source of metal deposition particularly in the branches.

One of the most important results of the study was that Ba and Fe concentrations increase with traffic density in all organs. These elements can be very dangerous for human health. Ba (barium), if swallowed, brain, liver, kidney and heart damage and swelling can be seen, reduces nerve reflexes, breathing difficulties, high blood pressure, heart rhythm disorders, muscle weakness, stomach irritations and reflux, inflammation, tumors, constipation, swallowing difficulty, and even damage to paralysis and death [42]. Fe (Iron) is a very important element for the human body, although it is a toxic substance, it is harmful to the body if taken too much. Fe height; excessive fatigue, pain in the joints, pain in the abdominal region, diabetes, rhythm disturbance in the heart, heart attack, heart failure disease, cirrhosis and liver cancer known as liver disease, impotence, infertility, skin color change, menstrual irregularity, osteoarthritis and osteoporosis , hair, eyebrow and eyelash loss, bloating of the liver and spleen, hypothyroidism, high blood sugar, depression, adrenal function problems, neurodegenerative disease and high liver enzymes can be seen. As a result of iron overload due to the high level of iron from food or beverages, Fe can accumulate in internal organs and cause fatal damage to the brain and liver [43]. Therefore, increasing Ba and Fe depending on traffic density is extremely dangerous for human health.

Ba and Fe have been the subject of many studies because they are important for human health. Batır [44] found that the highest concentrations were obtained in all organs of apples in his study on eight different species. In general, the lowest Ba concentrations were obtained in fruits [44]. Saleh [45] stated that Fe concentration in 6 species increased with traffic density. Saleh [45] states that Fe concentration in the subject species varies between 7,860 ppm and 40,573 ppm in areas with low traffic and between 13,033 ppm and 54,353 ppm in areas with high traffic. Similarly, Mossi [32] found that Fe concentration increased due to traffic density, Fe concentration was 45.95 ppm in areas where there was no traffic, and 60.17 ppm in areas with less traffic and 97.91 ppm in areas with high traffic. Ba and Fe have been the subject of numerous other studies on heavy metals [46-48].

Heavy metals in air may accumulate in plant leaves by leaf transfer following precipitation of atmospheric particles on leaf surfaces. The potential for absorbing nutrients, water and metals from leaf parts of plants has long been recognized. However, information about the uptake of metal by plant leaves from the atmosphere is very limited [14].

There are many factors affecting the penetration and accumulation of heavy metals in the air. Studies conducted to date have shown that the diffusion of heavy metals in the atmosphere and the introduction of plants into the plant is a very complex mechanism [14, 32]. The heavy metal accumulation potential of the plants grown in the same environment as well as plant species and plant organ, organelle structure, physico-chemical properties of metals, organelle morphology and surface area, organelle surface texture and size, plant habitus, duration of exposure to heavy metal and amount of particulate matter [14-16, 40]. In addition, environmental conditions, especially air humidity and precipitation, also affect the influx of heavy metals into the plant significantly [14, 35].

In addition to these factors, there are also other factors likely to affect the concentration of heavy metals. For example, the growth performance of plants, for example, morphological, anatomical and phenotypic characteristics, emerges as a result of the interaction of genetic structure and environmental conditions [49,50] and it is known that each genetic structure can give different responses to the same environmental conditions [24-26, 31, 51]. For example, different clones of the same species were found to have different resistance to water and frost stress [21, 24-26, 52]. The components of these factors are therefore likely to affect the factors that influence the uptake of heavy metals in the plant. Because the studies show that many phenological, morphological and anatomical characters are significantly affected by these factors [30, 53-56].

Heavy metal uptake and accumulation in plants are closely related to plant metabolism [14, 29,30]. Therefore, the stress level of the plant that significantly affects plant metabolism [22,23,57], plant origin [53] and hormone applications [58-61] can be expected to affect heavy metal uptake and accumulation of plants.

As a result, the change in heavy metal concentration in plants is the result of a complex mechanism due to the interaction of many factors. However, this mechanism is not fully solved. Information on the uptake of heavy metals from above-ground organs is very limited [14,32]. Therefore, the studies on the subject should be diversified and increased.

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Investigation of the Effects of Modified Bitumen on Asphalt Concrete Performance by Industrial Waste

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ABSTRACT

The increase in industrial wastes, which are released to the nature together with the developing technology, seriously damages both the environment and human health. The amount of waste materials is increasing day by day and the storage areas are limited. Nowadays, some waste materials are used in the construction sector for their usability and recovery. The use of waste as a recycling material is known to be used in road construction as a contribution to the content of bitumen, which constitutes the majority of the cost of asphalt concrete. In this study, the effects of modified bitumen on the performance characteristics of asphalt concrete containing waste were investigated. Samples were obtained with Marshall Design by using bitumen modified with these materials and their results were evaluated. When the test results are examined; it was observed that the Marshall strengths of the modified samples decreased in small amounts. However, all samples provide the required standard conditions. In this way, both environmental waste is evaluated and sustainable life is ensured.

Anahtar Kelimeler:
Bitüm,
Beton,
endüstriyel atık,
Marshall Dizayn,
Atık.

ÖZ

Gelişen teknoloji ile birlikte doğaya salınan endüstriyel atıklardaki artış, hem çevreye hem de insan sağlığına ciddi zarar vermektedir. Atık madde miktarı gün geçtikçe artmakta ve depolama alanları sınırlandırılmaktadır. Günümüzde inşaat sektöründe kullanılabilirlik ve geri kazanım için bazı atık maddeler kullanılmaktadır. Atıkların geri dönüşüm malzemesi olarak kullanılmasının, asfalt beton maliyetinin çoğunluğunu oluşturan bitüm içeriğine katkı olarak yol yapımında kullanıldığı bilinmektedir. Bu çalışmada, modifiye bitümün, atık içeren asfalt betonunun performans özelliklerine etkisi incelenmiştir. Bu malzemelerle modifiye edilmiş bitüm kullanılarak Marshall Tasarım ile örnekler alındı ve sonuçları değerlendirildi. Test sonuçları incelendiğinde; Modifiye örneklerin Marshall kuvvetlerinin az miktarda azaldığı gözlendi. Bununla birlikte, tüm numuneler gerekli standart koşulları sağlar. Bu şekilde, hem çevresel atık değerlendirilir hem de sürdürülebilir yaşam sağlanır.

1. Introduction

Nowadays, as a result of the widespread use of automobiles, millions of waste car tires that have long gone away in nature are emerging. Such a considerable amount of waste tires and the recycling methods of these materials have become a necessity to be used in different fields today. With the rapid increase of the world's population, the needs of people such as life, health food and shelter are increasing at the same rate in order to survive. With the increasing needs, the environment becomes polluted at the same speed. So much so that environmental pollution has become one of the most important problems of today. Considering all these problems, by evaluating the waste materials that create storage problems, especially in the coming years, it will contribute to the protection of the environment, which is thought to be in danger and to reduce the production cost of the product. Pollution of the environment occurs in two ways. They are the natural paths, the waste of all living things except human beings and the direct waste of human beings. In natural pollution, nature can clean the pollution in a short time with the recycling mechanism. However, human origin; especially, pollution caused by industrial activities remains in the nature for a long time and causes negative effects on people. Recycling of construction and demolition wastes has become an area of increasing interest due to its benefits for the protection of the economic and natural environment. In many countries, the importance of the issue has been emphasized in researches on the protection of the natural environment. Researchers have carried out studies revealing the technical details of the subject. The use of recycled materials ensures both the protection of nature and the economic use of natural resources, and gives new generations environmental awareness. In many countries, strict legal regulations have been introduced for the implementation of the recycling of construction waste [1-19].

In recent years, efforts to increase the performance characteristics of roads made with asphalt concrete have gained speed. The cost of the bitumen material has increased the importance of the use of these ground tires as an additive in asphalt concrete. Besides, glass fiber types have been used as additive material in industrial areas since 1940s. They are known for their ability to increase physical properties such as tensile strength, bending strength, impact and stiffness [1]. The effects of waste tires on binder asphalt concrete with Marshall Test and creep performance tests. For the bitumen samples with penetration values of 50-70 and 70-100, the waste tires of different shape and particle sizes were added to the aggregate in concrete asphalt. It has been observed that the asphalt concrete produced using waste material has similar performance characteristics as the asphalt concrete produced under standard conditions [20, 21].

The effect of the modified bitumen car tire on the fatigue behavior of the modified bitumen by using the constant pressure test method and comparing the fatigue time of the sample samples. 5% of the car used in the tire additive 50 times the fatigue time for the bitumen penetration increased by 100 times the fatigue duration of bitumen modification was observed to increase 23 times [22].

One of the experimental design methods used in the method was to examine the condition of the car tires used as additive in Type-2 asphalt concrete. The results of the experiment are as follows: waste rubber gradation sieve, mixture temperature 155 ° C, and aggregate gradation grad, bitumen ratio 5.5%, compression temperature 135 ° C and mixing time should be 15 minutes. The effects of 50-70 penetration bitumen on the performance characteristics of wear asphalt concrete, which have been used in certain proportions of waste rubber and glass fiber, were investigated. Samples were obtained with the traditional Marshall design. The void ratio, the void ratio, the practical specific gravity, and the Marshall strength as well as the void and aggregate filled void ratios were compared. Compliance with the necessary boundary conditions in the technical specifications is examined. In this way, it is aimed to evaluate both environmental wastes and sustainable life [1, 21-24].

2. Material and Method

The bituminous material utilized in street development comprises essentially of bitumen. Bitumen is a blend of hydrocarbons of regular starting point or a blend of pyrogenic (characteristic, heat-actuated) hydrocarbons, or a mix of both, more often than not in mix with non-metal subordinates, which might be as gas, fluid, semi-strong or solids. What's more, totally broke down in carbon disulfide. The bitumen can be characterized quickly as a mollified fastener, which is extraordinarily arranged for the quality and consistency of the bituminous coatings [25].

Asphalt, which is one of the most established designing materials, is a fastener which is found in the normal state or got amid the refining of unrefined petroleum, which has a solid restricting properties, which might be as strong, semi-strong and fluid, which may change from dull dark colored to dark. Asphalts can be partitioned into two gatherings as characteristic asphalts and counterfeit (asphalt) asphalts [26].

Common asphalts are generally found in nature blended with mineral substances. To make it accessible, you have to experience various activities. Normal asphalts are made out of oil by the activity of topographical powers and are commonly blended with mineral totals. Characteristic asphalts are characterized into shake asphalt and lake asphalt [26,27].

Shake asphalt is made out of extremely permeable limestone and, all the more once in a while, asphalt retention of sandstone. The mineral substance typically comprises 90% of the material and the bitumen proportion is about 10%. Shake asphalts are generally made out of mineral materials, for example, sand stone, limestone, dirt and blend of asphalt of 2 ~ 12% [28]. Lake asphalt is the most generally utilized and broadly known type of characteristic asphalt. It is the asphalt sort of mineral material which is spread in bitumen medium as fine grains. It is found as surface stores and above all is Trinidad lake asphalt. The material in the lake is a generally amazing blend of a semi-strong bitumen and fine mineral total [29-31].

Fake asphalts are gotten by refining of unrefined petroleum. These asphalts are additionally called refineries asphalts. The unrefined petroleum from the oil wells goes to the refinery. Here it is released into tanks with siphons. The raw petroleum is then exchanged to the warming towers and afterward conveyed to the refining towers. The effectively unstable parts are expelled from the highest point of these towers and are moved in the coolers. They structure light distillates. The less unstable ones likewise structure medium distillates and the heaviest flies structure substantial distillates. The primary asphalt-containing buildup materials gather at the base of the pinnacle [31-33]. Further refining of lingering materials yields street oils with a class of moderate restoring, leaving the asphalt concrete back. By changing the conditions, asphalt concrete is acquired in the ideal infiltration [34].

Asphalt concretes utilized in street asphalts are oil root asphalt arranged for use in bituminous coatings as far as properties and consistency. Asphalt bond must be warmed so as to have the capacity to be utilized for use. When it chills off, it solidifies again and goes about as a folio. Asphalt bonds are ordered by their level of infiltration, which demonstrates consistency and range from 10 to 300. As the level of entrance expands, the asphalt concrete diminishes and accordingly the coupling quality abatements. Asphalt bond and asphalt emulsions are the primary material [35]. The asphalt bond which is the essential material of asphalt concrete is gotten by blending a realized asphalt bond with a level of entrance. So as to utilize asphalt, shallow coatings and bituminous macaque, it is created to acquire a liquid asphalt which can be blended with total in virus state or at enough temperature to evaporate dampness in total surface. Other than being utilized as folios in the street, they are additionally utilized in preparing works. They are isolated into three gatherings as quick fix RC class, medium-speed fix MC class and moderate fix SC class. Also, in each class is isolated into classes as per their kinematic thickness esteems demonstrating their level of consistency. The higher the thickness of the asphalt, the more noteworthy the consistency of these numbers. For instance, MC 30 asphalt is a lot more slender and more liquid than MC-3000 [36-38]. As the asphalts are utilized out and about, just asphalt cement remains. This procedure is called restoring. The speedy restoring asphalts are acquired by blending an unstable dissolvable, for example, asphalt cement and fuel. They are utilized in virus atmospheres as they dry rapidly and in circumstances where the blend ought to be blended rapidly. In light of the quick combustibility, exceptionally cautious alert is required [38,39]. Medium speed relieving asphalts, asphalt cement and lamp fuel is gotten by blending a medium unpredictable dissolvable. Drying time is quicker [39, 40]. The moderate relieving asphalt are gotten by blending asphalt cement with a high breaking point oil or by direct refining of unrefined petroleum [40,41].

Asphalt emulsions are acquired by scattering a few micron distance across asphalt cement dots independently in water. Scattering of asphalt cement in water can be accomplished by blending. Be that as it may, the emulsion in this way acquired does not keep going long, and a little while later the asphalt dabs hold fast to one another and are isolated from the water. So as to avoid this circumstance, concoction added substances called emulsifiers are utilized. The emulsifier averts the asphalt dots from folding over them as a film. At the point when the asphalt emulsion is laid out and about, the emulsifier vanishes because of its assimilation by totals and residue in the street. This marvel is called cutting the emulsion. As indicated by these shear rates, asphalt emulsions are partitioned into three classes as quick cut, medium cut and moderate shear. These images show numbers and letters that demonstrate the thickness of the emulsion. It demonstrates that there is an emulsion cationic emulsion. A portion of the anionic emulsions seem to have high spinning qualities as estimated by the whirling test [41-44].

The terms anionic and cationic are identified with the electric charges around the bitumen grains. At the point when the two posts, the anode and the cathode are submerged in the fluid, the electric flow goes between the decidedly charged anode and the contrarily charged cathode. In the event that an electric flow is gone through an emulsion containing negative electric charged bitumen particles, the bitumen particles are conveyed in the anode and these emulsions are anionic. The emphatically charged bitumen particles are conveyed in the cathode and these emulsions are cationic. In non-ionic emulsions, bitumen particles are nonpartisan and are not conveyed to the two shafts [45].

Asphalt emulsions, surface coatings, groundwork applications, infiltration macadam coatings, ground adjustment and feeble totals are utilized in the impregnation procedure.

3. Result and Discussion

Bituminous blends are utilized as base and wearing courses in an asphalt structure to circulate stresses brought about by stacking and to shield fundamental unbound layers from the impacts of water. A bituminous blends have distinctive kinds of bothers like: exhaustion breaking, rutting, warm splitting, rubbing, and dampness weakness. Out of these rutting is the one that is destined to be an abrupt disappointment, rutting in an asphalt may happen because of poor plan of hot blend black-top. Different troubles are regularly long haul disappointments that appear following a couple of long periods of traffic. A portion of the components causing troubles in bituminous asphalts are high asphalt temperature, substantial hub loads, high tire weight and potentially insufficient fastener and blend particular. Execution of bituminous blends can be characterized by their capacity to oppose perpetual twisting, weariness splitting, dampness actuated harm, warm breaking, and the blend's general solidness. Total degree can influence all these and different properties, for example, slip opposition, field construct ability, and the black-top folio maturing attributes. Structuring a bituminous blend to address the issues of a specific clearing venture requires cautious determination of the total and bitumen to be utilized. A proper bitumen evaluation and substance must be chosen. A good total source and degree should likewise be picked to address the issues of the task. Every one of the four properties will influence the general execution of the bituminous blend. Bituminous blend is made out of roughly 95%, by weight, or 80%, by volume, mineral total. Accordingly it is vital to perceive how total degree can influence the major properties of bituminous blend [46].

The execution of a bituminous blend relies upon outer and inward conditions; the outside conditions being traffic load and natural and the inside conditions being properties of the materials, structure of the blend, plan of the blend, and procedure of the development. Bituminous blend comprises of bitumen folio, totals and air voids. The properties of a bituminous blend rely upon the nature of its segments, the development procedure, and the blend configuration extents [47].

Degree is characterized as the dissemination of molecule sizes communicated as a percent of the all out weight. On the off chance that the particular gravitates of the totals utilized are comparative, the degree in volume will be like the degree in weight. Degree is maybe the most vital property which influences practically all the vital properties of a bituminous blend, including firmness, solidness, toughness, penetrability, usefulness, weariness obstruction, frictional opposition, and protection from dampness harm [48].

Changeless disfigurement in bituminous asphalts, generally alluded to rutting, typically comprises of longitudinal sorrows in the wheel ways, which are an amassing of little measures of unrecoverable misshapen brought about by each heap application. Two instruments are engaged with the development of rutting: traffic intensification and material parallel development [49]. Intensification in a layer happens in the initial couple of summers in the wake of opening to traffic and the level of intensification relies upon the underlying compaction level. The sidelong development of material is identified with the shear obstruction of a bituminous blend material. The total precision and cover content are both significant in the blend shear property [50].

He rutting execution of a bituminous blend depends not just on the properties of the totals and fastener, yet in addition on how these materials cooperate in the blend. Rutting in bituminous blends is constrained by the qualities of the cover and totals and their connection. Rutting can be diminished by expanding the voids in the mineral total, building up least and most extreme air voids substance, restricting the measure of characteristic sand, setting up a base level of pulverized coarse and fine totals, utilizing stiffer cover, or by the utilization of coarser blend degrees. Total degree seemed to have more impact than total sort. He additionally inferred that the temperature powerlessness attributes of the black-top seem to have more impact at longer time of stacking [51].

Bitumen covers are visco-versatile materials whose protection from distortion under burden is extremely touchy to stacking time and temperature. The bitumen thickness straightforwardly influences the quality of bituminous cement in pressure (rutting) for the down to earth scope of temperatures. The log of asphalt opposition and of attachment differs legitimately with the log of black-top thickness [52].

Modulus of versatility in pressure was impacted by the sort of black-top, temperature and measure of horizontal control. The expansion in twisting is identified with the diminishing in fastener thickness at high temperatures (40ºC), in this way prompting a lower interlock between the totals. The commitment of the total skeleton towards the conduct of the blend turns out to be increasingly noteworthy at higher temperatures [53].

4. Conclusion

Asphalt concrete is an all-around exorbitant composite material. Overall investigations are gone for decreasing this expense. Then again, ecological contamination is likewise a major issue. In this examination, the utilization of waste from ecological squanders in asphalt concrete was explored. The outcomes can be abridged as pursues; The Marshall quality of tests arranged with altered bitumen is lower than the control tests. Nonetheless, the adjusted and control tests give toughness, which is the specialized determination of the wear layer. Practical explicit loads are higher in charge than in different examples. This is because of the empty structure shaped by the waste tires in the examples. Glass fiber has preferred execution attributes over examples containing just waste elastic. Glass fiber admixtures utilized as dry blend gave preferable outcomes over wet blend tests. Bitumen adjustment of glass strands is very troublesome. Since, contingent upon the kinds of headers set in the bitumen changed blender, there were issues of amassing and tying. This demonstrates the glass filaments added substance utilized in various extents can't be precisely assessed. In any case, an increasingly homogenous circulation can be gotten in the dry blend. Another issue is that the bitumen acquired from bitumen alterations of 1% and 2% glass strands has been very thick because of the way that the glass filaments added substance has a parallel component in expanding the thickness of the bitumen by the waste tire. The rotational viscos meter of the bitumen altered utilizing 2% glass strands demonstrates that the usefulness of the bitumen is very troublesome contrasted with different kinds of bitumen. Thinking about these issues, it was chosen that 2% of the glass filaments added substances ought to be added dry to the blend.

The glass fiber builds the example qualities by shaping a skeletal structure in the example. Glass fiber tests were lower than those containing just waste elastic, bringing about a progressively practical asphalt concrete. Ecological waste is assessed by the utilization of waste elastic and glass fiber. Feasible condition and life are guaranteed.

5. References

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Molecular Identification and Characterization of LEA Proteins in Jujube Genome

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ABSTRACT

LEA proteins, which are involved in the normal growth and development processes of plants, also play a protective role against abiotic stresses such as salt stress and drought. Although the *LEA* gene family has been identified in many plants to date, no comprehensive study of the characterization of LEA-encoding genes in the jujube (*Ziziphus jujuba* Mill.) genome have been performed. As being the best-known member of Rhamnaceae family, jujube (*Ziziphus jujuba* Mill.) is grown in Turkey as well as shows distribution especially in subtropical and tropical regions of the world. Jujube, containing high amounts of vitamin C and sugar; has economical and biological importance with anticancer and anti-inflammatory effects. In this study, it was aimed to define and characterize *LEA* genes in jujube genome in detail by using bioinformatics tools. The results of the study will provide comprehensive data about the *LEA* gene family and will present preliminary information for the functional research of jujube LEA proteins.

Anahtar Kelimeler:
LEA proteinleri,
Ziziphus jujuba Mill.,
Genom çapında analiz,
Biyoinformatik.

ÖZ

Bitkilerin normal büyüme ve gelişme süreçlerinde görev alan LEA proteinleri, özellikle tuz stresi ve kuraklık gibi abiyotik stresler karşısında da koruyucu rol üstlenmektedir. Bu zamana kadar birçok bitkide *LEA* gen ailesi tanımlanmış olmasına karşın, hünnap (*Ziziphus jujuba* Mill.) genomunda LEA kodlayan genlerin karakterizasyonuna dair kapsamlı bir çalışma yapılmamıştır. Rhamnaceae ailesinin en bilinen üyesi olan hünnap (*Ziziphus jujuba* Mill.), Türkiye'de yetiştirildiği gibi dünyada da özellikle subtropik ve tropik bölgelerde dağılım göstermektedir. Yüksek miktarda C vitamini ve şeker içeren hünnap; antikanser ve anti-inflamatuvar etkileri ile ekonomik ve biyolojik öneme sahiptir. Bu çalışmada biyoinformatik araçlar kullanılarak hünnap genomunda *LEA* genlerinin detaylı olarak tanımlanması ve karakterizasyonu amaçlanmıştır. Çalışma sonuçları, literature *LEA* gen ailesi ile ilgili kapsamlı bilgi sağlamakla birlikte hünnap LEA proteinleri ile ilgili fonksiyonel araştırmalara ön bilgi sunmaktadır.

1. Introduction

Plants always interact with the external environment and they do not have the ability to avoid like other living things, so they have to adapt to unsuitable environmental conditions. Stress is a situation that arises from the environmental conditions change so much that the normal growth and development of a plant is influenced negatively. Plants compete against many stress factors throughout their lifespan [1]. They adapt to environmental changes such as cold, salinity, drought, hormone applications, heavy metals, by regulating the expression of different stress genes such as various transcription factors, chaperones, osmotic preservatives, free radical scavengers [2]. LEA proteins that were initially discovered in cottonseed by the high accumulation of embryogenesis in the ripening period are one of the families of proteins regulated under abiotic stress conditions. LEA proteins, first identified in cotton, were then discovered in seed, seedling and stem of many plants such as wheat, corn, rice, potato, apple, vine, tomato, soybean, carrot and Arabidopsis [3].

LEA proteins, which are involved in the normal plant development, are induced in conditions such as desiccation and ABA stress, thus conserving the plant from adverse conditions [4, 5]. RNA-seq analysis in *Prunus mume* (Chinese plum) showed that the 30 *PmLEA* genes were expressed in varying proportions in the flower, root, stem, leaf and fruit of the plant, and 22 of these genes were induced in high amounts in the flower of the plant. RNA-seq analysis in Chinese plum showed that the 30 *PmLEA* genes were expressed in variable rates in the flower, root, stem, leaf and fruit of the plant and 22 of these genes were stimulated in high amounts in the flower of the plant. In addition, RT-PCR performed in the same plant after ABA application, 19 *PmLEA* genes were detected to be up-regulated under ABA stress [6]. 26 *MeLEA* genes were identified in cassava plant (*Manihot esculenta* Crantz) after it was subjected to drought, salt, osmotic pressure, cold, ABA and H_2O_2 stress factors. Especially, 9 of 26 *MeLEA* genes took part in stress response and signaling [7]. In addition to these studies, LEA proteins protected the enzymes from aggregation and inactivation under stress conditions such as LDH, fumarase, citrate synthase, malate dehydrogenase [8].

Although there are different opinions on the classification of LEA proteins, based on conserved motif sequences, it is possible to classify as LEA (1-6), Dehydrin and Seed Maturation Protein (SMP). According to biochemical structure of LEA proteins, whereas Ala, Ser and Gly amino acids are situated in high quantity in the structure of highly hydrophilic LEA proteins; Cys and Trp amino acids are present in small amounts [8, 9]. Jujube (*Ziziphus jujuba* Mill.) is a bramble fruit tree that grows mainly in the subtropical and tropical regions and also America, Europe and Australia, especially in South and East Asia. In Turkey, jujube especially is grown in Mediterranean and Aegean Region also is found in the Central Anatolia and Marmara Region [10, 11]. Jujube, the most economically valuable member of the Rhamnaceae family, contains high vitamin C and sugar content and the cultivation sites are becoming widespread all over the world. Jujube also can grow in nutritionally poor soil and arid areas also can tolerate drought and salinity [12]. Jujube demonstrates neuroprotective activities, antioxidative, anti-inflammatory and anticancer activity in terms of its contents as triterpenic acid active substances, polysaccharide and flavonoid [13].

Liu et al. (2014) declared its whole genome sequence and in 2016, its chloroplast genome sequence was also completed. Jujube was found to contain 32000 genes [14]. However, no studies have been fulfilled to identify and characterize jujube genes other than *MAPKK* gene family [15]. In the present study, it was aimed to identify the *ZjuLEA* gene family and LEA proteins by revealing gene structure, conserved motifs, chromosomal distributions etc. in jujube by using bioinformatics tools.

2. Material and Method

Determination of *Lea* Genes in Jujube Genome

In order to ascertain *LEA* genes in jujube genome, firstly LEAP database was used to obtain LEA protein sequences (http://forge.info.univ-angers.fr/~gh/Leadb/index.php, PMID: 20359361). Secondly, jujube genome sequence was retrieved from NCBI database. Afterwards BLASTP search was run to detect homologous LEA protein sequences in jujube genome. Predicted ZjuLEA proteins were confirmed by analyzing conserved regions with Pfam database (https://pfam.xfam.org). Expasy PROTPARAM (https://web.expasy.org/protparam/) database was used to identify certain biochemical properties such as amino acid length, molecular weight, and theoretical isoelectric point of the proteins.

Phylogenetic Analysis and Identification of Conserved Motifs

Aligned amino acid sequences using ClustalW were utilized to conduct a phylogenetic tree with MEGA7 (Molecular Evolutionary Genetic Analysis) software. Genetic relationships were deduced from maximum likelihood method with 1000 bootstrap value. This tree was regulated in Interactive Tree of Life (ITOL) database [16] in order to determine the classes formed in the phylogenetic tree constructed. For detection of the conserved motifs of ZjuLEA proteins, MEME Suit online tool was used (http://meme-suite.org).

Chromosome and Exon-Intron Localizations of *ZjuLEA* Genes

Estimated positions of *ZjuLEA* genes were determined with PHYTOZOME12 database (https://phytozome.jgi.doe.gov/pz/portal.html). Exon-intron organizations of *ZjuLEAs* were enlightened via comparing coding sequences (CDS) with genomic sequences through Online Gene Structure Display Server (GSDS) tool (http://gsds.cbi.pku.edu.cn).

Gene Ontology Analysis and Homology Modelling of ZjuLEA Proteins

The Blast2GO program [17]) is a bioinformatics program that applies functional analogy, has loaded amino acid sequences of ZjuLEA proteins. Functional analysis of ZjuLEA proteins in terms of possible biological roles, cellular localization and molecular processes were provided with Blast2GO program (https://www.blast2go.com). Estimated three-dimensional structure of ZjuLEA proteins were anticipated with online protein structure prediction server Phyre2 (Protein Homology/ analogY Recognition Engine V 2.0).

Determination of ZjuLEA Gene Targetting miRNAs

In order to find out miRNAs targeting ZjuLEA transcripts, miRBase v21 (http://www.mirbase.org/) and psRNATarget (Plant Small RNA Target Analysis Server) were utilized (http://plantgrn.noble.org/psRNATarget/).

Orthologous Relationships of ZjuLEA Proteins

Amino acid sequences from *Arabidopsis thaliana*, banana (*Musa acuminate*), orange (*Citrus sinensis*) and peach (*Prunus persica*) were used for comparison of peptide sequences of ZjuLEA proteins with BlastP in Phytozome database. CLC Genomic Workbench was utilized to analyze duplication assessment of ZjuLEA proteins.

Synonymous and Non-synonymous Change Rates

ZjuLEA protein sequences and orthologs in peach, banana, orange and Arabidopsis were aligned using ClustalOmega online tool. PAL2NAL online tool was utilized to calculate homologous (Ks) and non-homologous (Ka) change rates via alignment of amino acid sequences of orthologous pairs and their respective cDNA sequences. Time (million years ago, Mya) of duplication and divergence of each *LEA* genes were calculated with the equation T=Ks/2k ($k = 6.5 \times 10^{-9}$) [18].

2. Result and Discussion

Determination of *Lea* Genes in Jujube Genome

According to Blastp and Pfam analysis, a total of *93 LEA* genes (*ZjuLEA1-93*) were identified in jujube genome. *LEA* genes diversely distributed across various taxonomic groups. 79 *LEA* genes in cucumber, 74 *StLEA* genes in potato, 68 *SbLEA* in sorghum, 60 *VvLEA* in grape, 33 in tea plant and 27 members in tomato were reported in previous studies [18–23]. Although number of *LEA* genes shows great variety in plants, it seems that allopolyploids tend to have higher numbers. For example, in the study of cotton Magwanga et al. identified 242 *LEA* genes in *G. hirsutum*, 142 in *G. raimondii*, 136 in *G. arboretum.* Similarly, Liu et al. reported 121 *LEA* genes in wheat and Liang et al. confirmed 108 members in canola [24–26]. On the contrary, aquatic plants *Physcomitrella patens* and *Lotus japonicus* have only 18 and 19 *LEAs*, respectively suggesting terrestrial plants subjected to drought stress seem to have more *LEAs* than the aquatics [20, 27-28]. Generally, similar number and distribution of *LEA* genes are expected between close phylogenetic relationship and group classifications. However, being both members of Rosales, Chinese plum (*Prunus mume*) and jujube have distinct gene numbers as 30 and 93 *LEAs*, respectively. Evolutionary variations of the whole genomes and extensive changes in the environment could have contributed to this occurrence.

Amino acid length of ZjuLEA proteins varied between 89-515 amino acids in length. Molecular weight of the proteins ranged from 4.14982 kDa to 29.12380 kDa. Isoelectric points (pI) of ZjuLEA proteins changing from 4.72 to10.81 and most of the proteins (78 proteins) showed alkaline character (**Supplementary Table S1 in appendix**). Consistent with our results *Brachypodium distachyon*, cucumber and tomato LEA proteins also showed basic character [18, 29-30].

Phylogenetic Analysis and Identification of Conserved Motifs

According to conserved domain analysis, *ZjuLEA* genes classified into 6 main subfamilies namely *ZjuLEA1*, *ZjuLEA2*, *ZjuLEA3*, *ZjuLEA4*, *ZjuLEA5* (Small hydrophilic plant seed protein), *ZjuLEA6* (Late embryogenesis abundant protein 18). *ZjuLEA2* was the largest family with 60 members while *ZjuLEA4* and *ZjuLEA6* subfamilies contained only one gene each. Consistent with our results, LEA6 subfamily is the smallest group in various plant species like grape, wheat [21, 25]. In their work, with 60 genomes of diverse plant species Artur et al. stated *LEA6* group as the smallest subfamily with 89 identified genes while *LEA2* subfamily as the most abundant with 3126 genes [31]. Group 2 LEA proteins was found to accumulate in several plant tissues not only during normal growth conditions but also with desiccation stress [8]. Several previous studies on tea plant, grape, sorghum, potato, cucumber, cotton also reported *LEA2* genes as predominant group as well. Segmental and tandem duplications and transpositional events could be the main reasons of expansion of *LEA2* genes among higher plants [21, 31].

To understand the evolutionary relationships of 93 ZjuLEA proteins, a phylogenetic tree was created using maximum likelihood method with 1000 bootstrap value. Based on the phylogenetic tree, *ZjuLEAs* divided into six main clusters (Cluster1-6) (**Figure 1**). Although distributed to all of the clusters dominantly, *ZjuLEA2* genes mostly located in Cluster-2. The only members of *LEA4* and *LEA6* subfamilies placed in Cluster-6 and Cluster-5, respectively. Also, all members of the *LEA5* subfamily (*ZjuLEA-24*, *ZjuLEA-55* and *ZjuLEA-56*) located in Cluster-4.

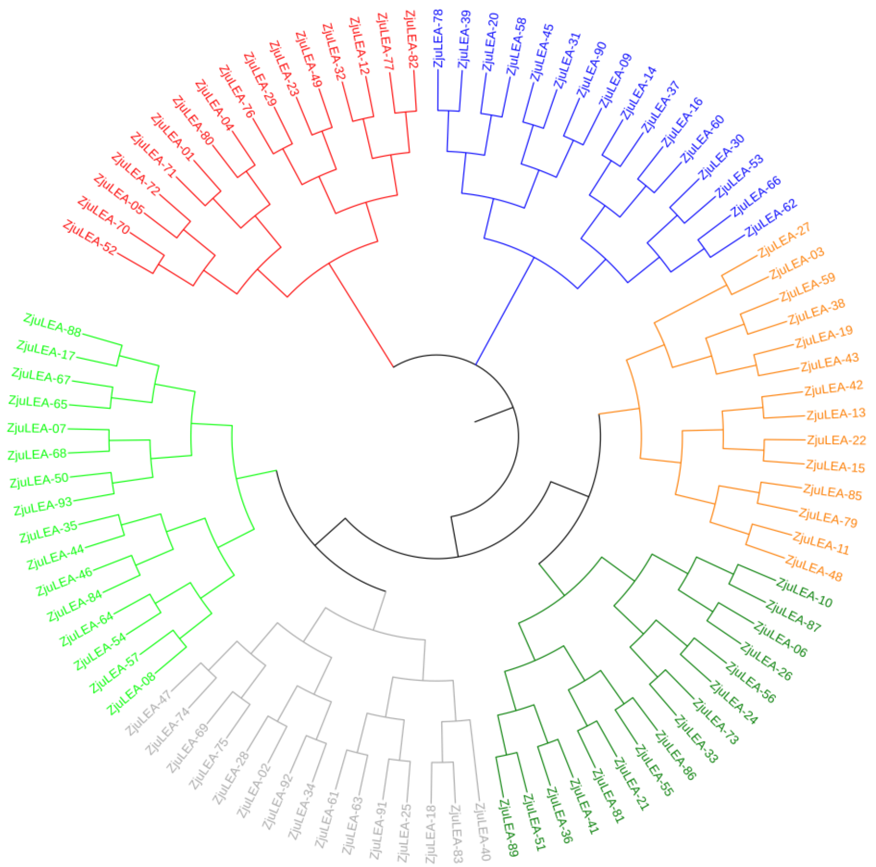

Figure 1. Phylogenetic tree of jujube LEA gene family. The proteins were divided into six distinct clusters: Cluster 1-red, Cluster 2-blue, Cluster 3-orange, Cluster 4-dark green, Cluster 5-grey, Cluster 6-light green colored

Chromosome and Exon-Intron Localizations of *ZjuLEA* Genes

In order to understand LEA subfamilies and phylogenetic tree profoundly, conserved motif compositions and exon-intron structure found in ZjuLEA proteins were examined. 37 of *ZjuLEA* genes had no introns whereas the other genes had one or two introns except *ZjuLEA8* which was the only gene with 3 introns (**Figure 2**). Major part of intronless genes were accumulated in *ZjuLEA2* subgroup. Members of *ZjuLEA1*, *ZjuLEA3*, *ZjuLEA5* subfamilies had only one intron region. Stress related genes reported to have smaller number of introns so as to respond immediately under stress conditions. Consistent with our results, Chinese plum, tomato and potato had one or two introns. All members of *LEA5* subfamily *(ZjuLEA24, ZjuLEA55 and ZjuLEA56)* localized in 4th cluster, supporting the phenomena that closely related *LEAs* had similar exon-intron feature [22, 24].

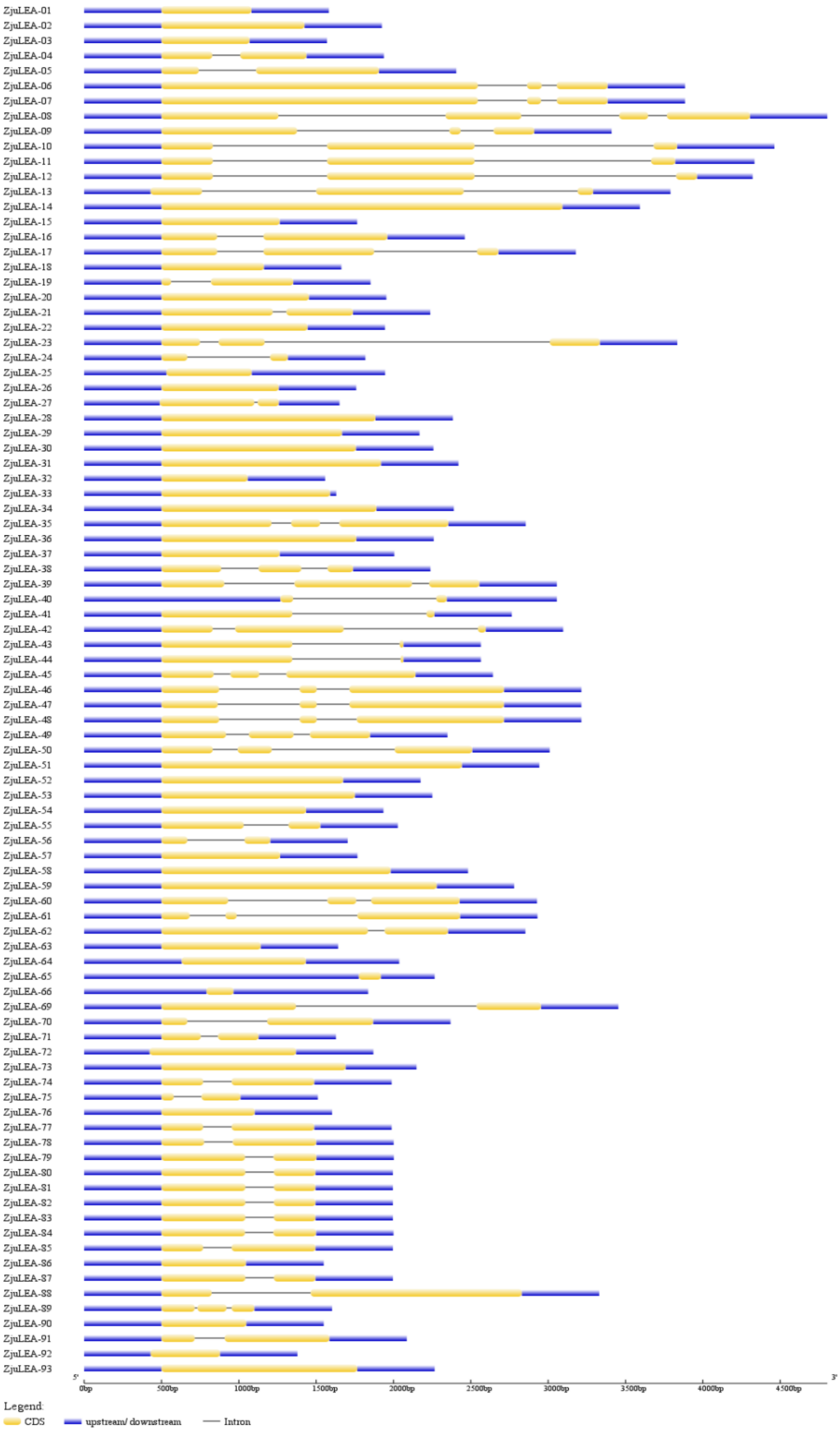

Figure 2. Exon-intron structure of *ZjuLEA* genes

On the other side, *LEA2* group members were predominant in all clusters of phylogenetic tree. Distribution of same group members between different clusters could be explained by significant motif composition differences. A total of twenty motifs predicted for ZjuLEA proteins (**Table 1**). Similar motif organization was observed between all LEA3 proteins sharing motif 1, motif 2 and motif 9 but located in different clusters of the phylogenetic tree. Some members (ZjuLEA02, ZjuLEA15, ZjuLEA20, ZjuLEA28, ZjuLEA63, ZjuLEA66, ZjuLEA68, ZjuLEA69, ZjuLEA93) of LEA2 proteins included motif 3, 4, 6 and 12 while some members (ZjuLEA01, ZjuLEA06, ZjuLEA25, ZjuLEA40, ZjuLEA53, ZjuLEA54, ZjuLEA58, ZjuLEA59, ZjuLEA76, ZjuLEA86, ZjuLEA89, ZjuLEA90) shared motif 3, 13, 14. However, motif 3 was the common conserved sequence present in all LEA2 proteins. Diverse motif patterns in the same group suggesting functional variations between the proteins [26, 32].

Table 1. 30 different motifs identified in ZjuLEA proteins

Motif No.	Sites	*E*-value	Amino acid sequence composition of the motif	Width
Motif 1	13	2.4e-480	GSGRNVVKKSGEEIVGSTEKVSWTPDPVTGYYRPENGAQEIDVAELRAML	50
Motif 2	12	5.4e-231	MARSFSNAKLLSALVVDGFSTAISRRGYA	29
Motif 3	51	4.0e-169	IJWLVLRPKKPKFTV	15
Motif 4	35	1.8e-150	ARNPNKKIGIYYDRL	15
Motif 5	4	7.6e-103	DYEVWLCDVSIGGAELLKSTQINKNGITYIDVPITFRPKDFGSALWDMMR	50
Motif 6	4	2.0e-094	EHENDKDKEKGGFIEKVKDFIHDIGEKIEEAIGFGKPTADVTAIHIPSIN	50
Motif 7	4	2.7e-093	RLTLPVEKTGEIPIPYKPDIDIEKIKFEQFSFEETVAVLHLKLENKNDFD	50
Motif 8	7	1.4e-122	IDINYLIESDGRKLVSGLIPDAGTIHAHGEETVKIPVSLIYDDIKNTYDD	50
Motif 9	12	2.2e-092	ASQGVVSSVARGGAG	15
Motif 10	19	3.0e-062	RSCCCCCTCWL	11
Motif 11	34	2.0e-113	LPPFYQGHKNTTVLSVVLGGQ	21
Motif 12	23	2.0e-088	TGVVPJDLKLLGRVRWKVGTW	21
Motif 13	15	3.2e-122	VKVKNPNFGSFKYDNSTVSFSYRGSVVGZVRIQKGKAKAR	40
Motif 14	15	4.2e-106	DLSSGVLTLNSNTKMTGKVKLJGIIKKKSAEMBCTISINV	41
Motif 15	7	6.8e-095	GHIDVDTPFGAMKLPISKEGGTTRLKKKKEDGGDDDDDDED	41
Motif 16	3	4.6e-069	WIGTSWCWSENAMDNARERADIAAGNAKLRAQETMQDARENTNSWTDWAF	50
Motif 17	6	2.9e-059	AITYGEDKEATAYNEGKKPVEZSDAAAIZAGEPRDTGNYEFAPGGASKAA	50
Motif 18	3	1.4e-049	EEAKQKISIGSDNTEEAKVPMSEAIDFGIEKASNAYDEAKRKFNQASNMA	50
Motif 19	4	5.8e-044	YGVYVKCDVLVGIKKGVLGQVPLLGSPGC	29
Motif 20	4	6.7e-039	ENFYIGEGSDFTGVPTDMJSMNASVKLTFRNPATFFGIHVSSTPJDLSYS	50

ZjuLEA genes unevenly spread through all twelve chromosomes of jujube. Chromosome 1, which is the largest chromosome of jujube genome, included the highest content of genes with the number of thirteen [14]. Twelve genes located on Chromosome 12 and both Chromosome 2 and 8 had 10 *ZjuLEA* genes each. On the other side, Chromosome

7 and 10 had only one member *ZjuLEA38 and ZjuLEA51*, respectively. In addition, a total of 22 *ZjuLEA* genes could not place on any chromosome and indicated on scaffold base (**Figure 3**).

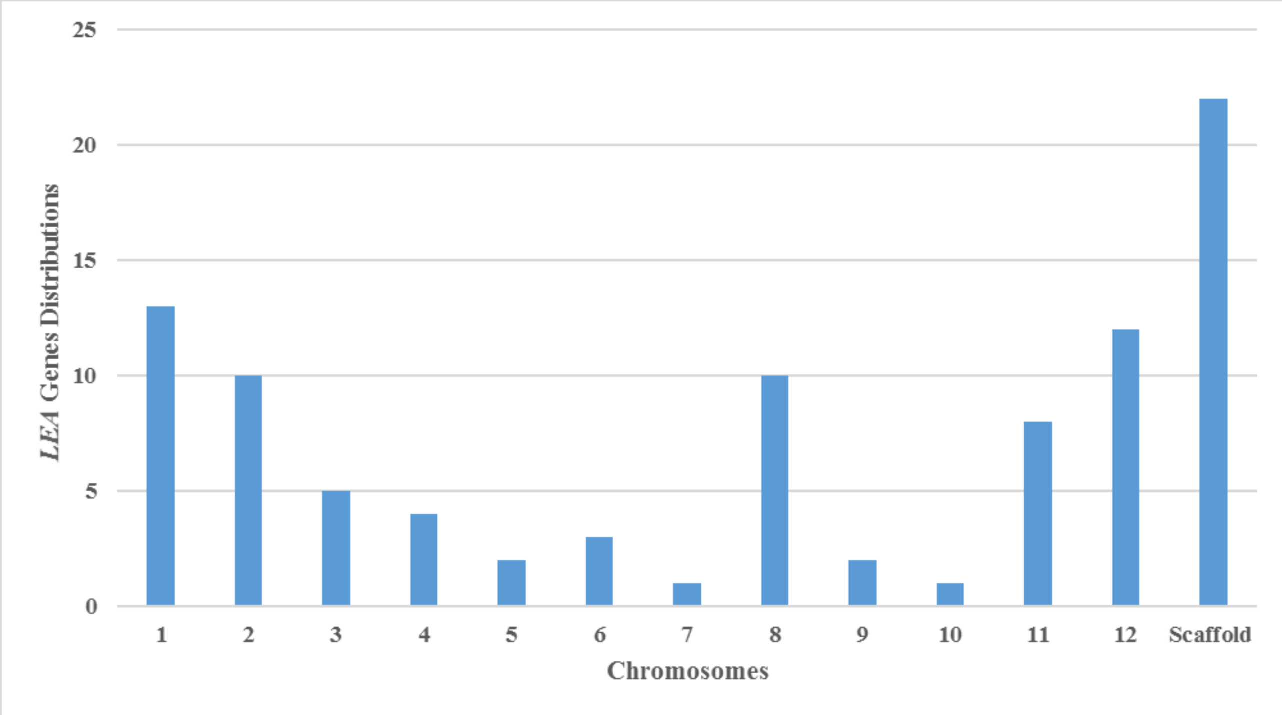

Figure 3. Chromosomal distribution of *LEA* genes in jujube

Gene Ontology Analysis and Homology Modelling of ZjuLEA Proteins

The cellular component, biological process and molecular function of *ZjuLEA* genes analysis were performed using the Blast2GO program. The ZjuLEA proteins mainly play part in response to stimulus and also in single-organism process, signaling, cellular process, regulation of biological process and biological regulation. LEA proteins especially overexpresses in stress conditions and mostly have role in protecting the organism. Altunoglu et al. [18] analyzed the LEA proteins in cucumber and they declared that these proteins mostly have role in response stimulus. LEA proteins of cotton exposed to drought stress was also investigated and they are mostly responsible for response stimulus. In addition, they have announced that most of them got signal transducer activity [24]. Almost all ZjuLEA proteins had signal transducer activity and some of them possessed catalytic activity. The cellular components of *LEA* genes of cotton [24] and *Vitis vinifera* [21] were exhibited in membrane and membrane parts. When investigated cellular components of ZjuLEA proteins, it was declared that most of them are distributed in the membrane and membrane parts. Also they appeared in cell part, cell, cell junction, symplast and organelle (**Figure 4**).

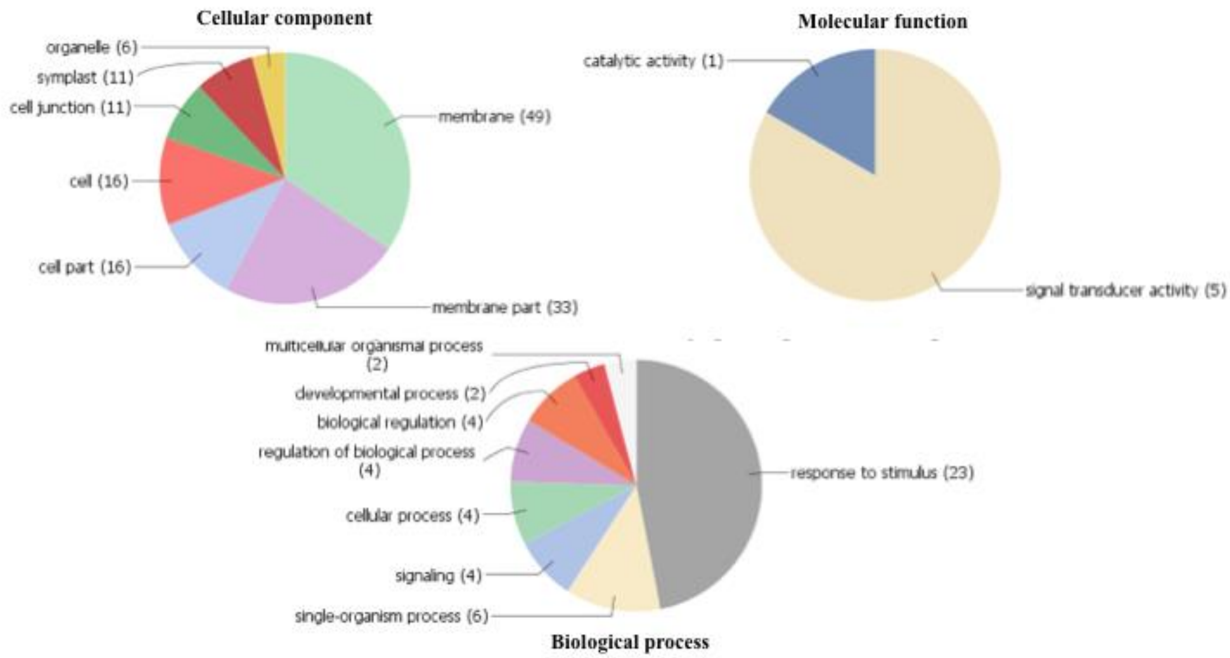

Figure 4. Gene ontology analysis of ZjuLEA proteins

Determination of ZjuLEA Gene Targetting miRNAs

MicroRNAs (miRNAs) which are approximately 21-24 base length are noncoding RNA molecules taking important part in regulation of gene expression in eukaryotes and viruses [33]. miRNAs are in interaction with mRNA that cause degradation and repression of translation [34]. When analyzed miRNAs targeting to *ZjuLEA* genes, the most targeted *ZjuLEA* genes by miRNAs are respectively *ZjuLEA-88* (33 miRNAs), *ZjuLEA-29* (31 miRNAs), *ZjuLEA-28* (30 miRNAs) and *ZjuLEA-6* (26 miRNAs) **(Figure 5)**. In addition, *ZjuLEA-24*, *ZjuLEA-38*, *ZjuLEA-55*, *ZjuLEA-57*, *ZjuLEA-61* and *ZjuLEA-64* genes was not targeted any miRNAs (**Supplementary Table S2 in appendix**). One of the most preserved miRNAs in plants during evolutionary process is miR156. miR156 and miR157 extremely similar and highly conserved in plants [35]. Kavas et al. [36] studied that the *SBP* genes of potato commonly targeted by miR156 and miR157. *HSP70* genes of common bean targeted by twenty-four miRNAs and one of them is miR156 [37]. In the present study, majority of *ZjuLEA* genes were targeted by miR156 (58 genes) and miR157 (24 genes).

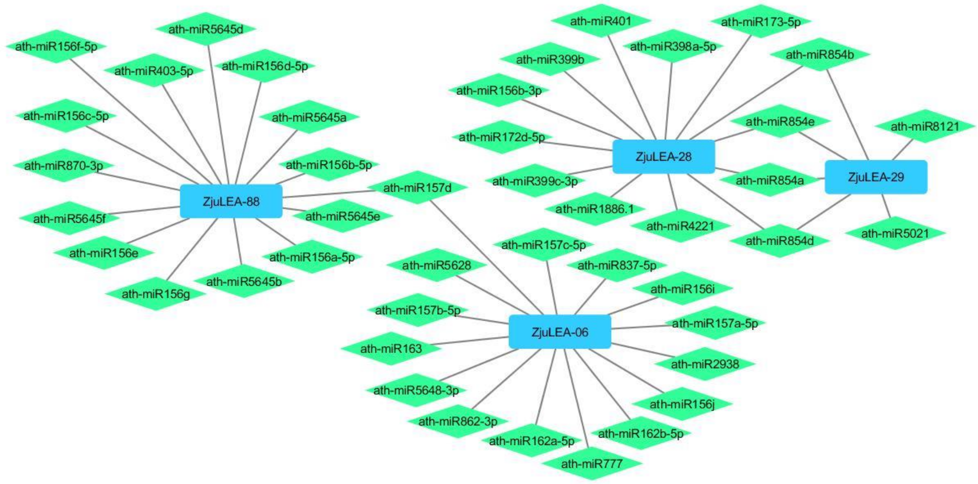

Figure 5. The most targeted *ZjuLEA* genes and their targeting miRNAs

Orthologous Relationships of ZjuLEA Proteins

Estimated three-dimensional structures of ZjuLEA proteins which aligns Hidden-Markov models search were done by selecting the intensive mode in the Phyre2 database. As a result of modeling ZjuLEA proteins, it was seen that α-helix structure dominated in ZjuLEA proteins (**Figure 6**). Despite both α-helix and β-sheets structure of LEA proteins are created during slow-drying, α-helix are only created during rapid-drying [38, 39]. LEA proteins are composed of a facultative and non-periodic linear α-helix which built the main hydrophobic interaction between monomers without thermodynamically dominant state [25]. α-helical structure was reported to be the dominant form under dry state of FTIR analysis in *Typha latifolia*, soybean, pea, a nematode and a rotifer [40]. According to the molecular function of ZjuLEA proteins, the α-helix structure correlates with the role of ZjuLEA proteins.

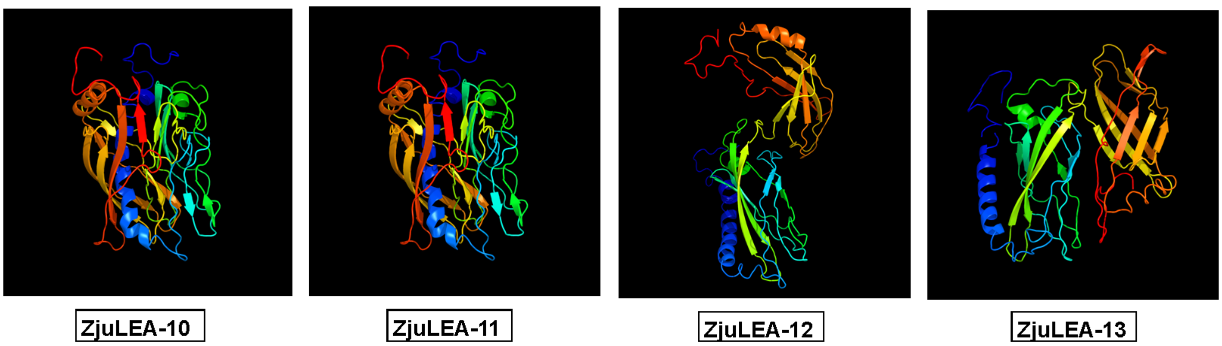

Figure 6. Predicted three-dimensional structure of LEA proteins

Synonymous and Non-synonymous Change Rates

To evaluate the timing of gene duplication results in genome, in addition to divergence of orthologues, non-synonymous (Ka) versus the synonymous (Ks) substitution rate (Ka/Ks) was calculated for 54 tandem duplicated *ZjuLEA* genes to assess evolutionary distribution of *ZjuLEA* gene family. Substitution rates estimated for orthologous genes of *ZjuLEA* from orange (*Citrus sinensis*), banana (*Musa accuminata*), peach (*Prunus persica*) and *Arabidopsis* *thaliana* (**Supplementary Table S3 in appendix**). Mean average of Ka/Ks ratios between jujube and *Arabidopsis*, banana, orange and peach were 0.06, 1.11, 0.09 and 0.12, respectively. When the divergence times between *ZjuLEA* and genes from other fruit species were analyzed, the latest separated genes from *ZjuLEA* were peach genes with mean of 84 MYA (million years ago). The average divergence time of jujube from orange, *Arabidopsis* and banana was 90, 162 and 262 MYA, respectively (**Figure 7).** In addition, the most ortologous genes were determined between jujube and peach *LEA* genes. According to divergence time and ortologous genes of jujube and other plants, jujube and peach may be closer than other plants. Segmental and tandem duplications make possible gene family enlargement [23, 41]. Genome wide studies of *LEA* genes exhibited that 22 genes in tomato [30], eight genes in potato [42], eight genes in purple false brome [29], 17 genes in Chinese plum [6], 56 genes in cucumber [18] and 42 genes in Arabidopsis [40] appeared segmental and tandem duplication. These duplications can be dedicated to *LEA* gene family extension between various plants.

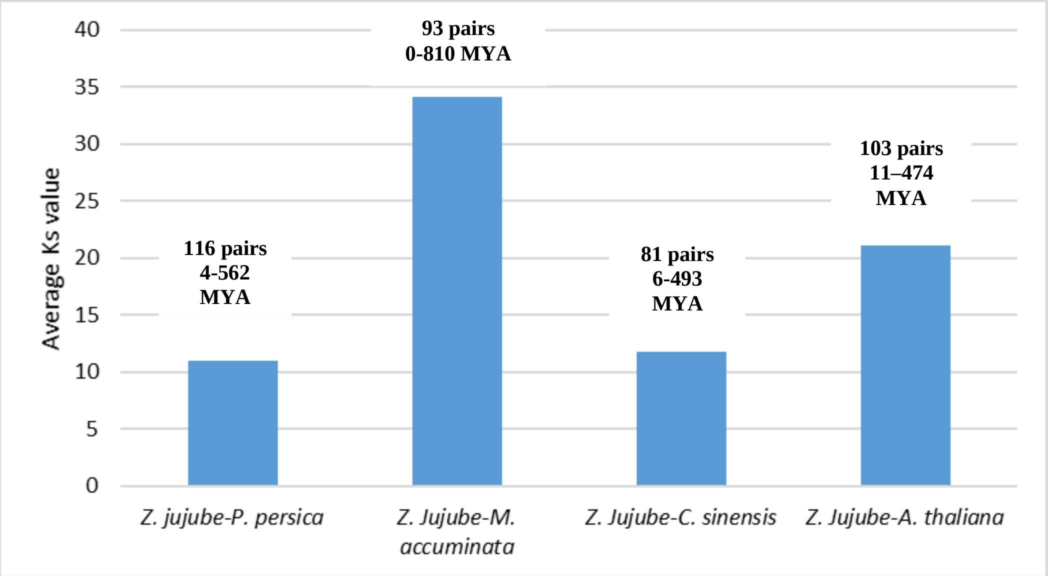

Figure 7. Estimation of gene duplications and divergence times (MYA) of *ZjuLEA* genes with orthologous *LEA* gene pairs between *Z. jujube*, *Prunus persica* (peach), *Musa accuminata* (banana), *Citrus sinensis* (orange) and *Arabidopsis thaliana*

As a result, a total of 93 *ZjuLEA* genes were identified and characterized in terms of phylogenetic analysis, estimation of 3D structure, miRNA identification and duplication events. These results can be used for identification of *LEA* genes in other organisms and functional characterization for agronomical traits in future studies.

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Appendix

Supplementary Table S1. Catalog of *ZjuLEA*s genes.

ID	Domain	NCBI Accession No.	Physical position on Ziziphus jujuba genome			Protein length (aa)	Molecular weight (Da)	pI	Instability index	Stable or unstable
			Chromosome	Start position (bp)	End Position (bp)					
ZjuLEA-01	LEA_2	XP_015883598.1	Chr1	13,803,284	13,803,865	193	21460,93	8,67	26,23	stable
ZjuLEA-02	LEA_2	XP_015884343.1	Chr1	14,115,965	14,116,889	225	25390,02	9,54	38,48	stable
ZjuLEA-03	LEA_2	XP_015883649.1	Chr1	14,119,099	14,199,668	189	21505,05	9,86	32,89	stable
ZjuLEA-04	LEA_1	XP_015895645.1	Chr1	30,737,488	30,738,425	105	11396,14	9,30	30,05	stable
ZjuLEA-05	Root cap	XP_015895968.1	Chr1	31,107,215	31,108,620	344	38130,23	7,83	34,88	stable
ZjuLEA-06	LEA_2	XP_015902379.1	Chr1	36,661,028	36,663,912	251	28119,34	9,68	41,28	unstable
ZjuLEA-07	LEA_2	XP_015902388.1	Chr1	36,661,028	36,663,912	235	26444,30	9,39	41,82	unstable
ZjuLEA-08	LEA_2	XP_015867106.1	Chr1	39,272,239	39,276,043	477	43200,00	10,04	69,51	unstable
ZjuLEA-09	LEA_2	XP_015867462.1	Chr1	39,467,779	39,470,188	217	24398,16	7,72	48,54	unstable
ZjuLEA-10	LEA_2	XP_015867988.1	Chr1	39,921,650	39,925,112	318	35360,27	4,72	21,29	stable
ZjuLEA-11	LEA_2	XP_015867996.1	Chr1	39,921,650	39,925,112	318	35360,27	4,72	21,29	stable
ZjuLEA-12	LEA_2	XP_015868000.1	Chr1	39,921,650	39,925,112	318	35360,27	4,72	21,29	stable
ZjuLEA-13	LEA_2	XP_015867981.1	Chr1	39,921,650	39,925,112	318	35360,27	4,72	21,29	stable
ZjuLEA-14	LEA_2	XP_015872567.1	Chr2	343,256	345,848	253	27580,43	10,53	49,23	unstable
ZjuLEA-15	LEA_2	XP_015873001.1	Chr2	337,886	338,65	215	23913,84	9,59	32,41	stable
ZjuLEA-16	LEA_2	XP_015873376.1	Chr2	2,716,331	2,718,509	275	30353,98	9,40	53.99	unstable
ZjuLEA-17	LEA_2	XP_015873377.1	Chr2	2,716,331	2,718,519	275	30353,98	9,04	53.98	unstable
ZjuLEA-18	UD	XP_015873480.1	Chr2	3,794,354	3,795,016	220	24426,92	9,16	57,72	unstable
ZjuLEA-19	UD	XP_015873626.1	Chr2	5,630,277	5,631,128	197	22881,57	9,79	49,76	unstable
ZjuLEA-20	LEA_2	XP_015873634.1	Chr2	5,640,567	5,641,520	199	22816,54	9,42	38,74	stable
ZjuLEA-21	Root cap	XP_015874391.1	Chr2	14,129,616	14,130,853	382	41380,89	8,48	12,96	stable
ZjuLEA-22	LEA_2	XP_015874632.1	Chr2	18,035,416	18,036,360	182	19846,74	5,85	29,00	stable
ZjuLEA-23	LEA_2	XP_015875454.1	Chr2	23,776,051	23,778,885	289	29826,80	5,10	34,01	stable

ZjuLEA-24	SMP	XP_015877411.1	Chr3	17,110,931	17,111,748	93	10012,93	6,13	27,33	stable
ZjuLEA-25	LEA_2	XP_015878291.1	Chr3	24,498,287	24,498,937	216	23655,41	9,71	32.88	stable
ZjuLEA-26	LEA_2	XP_015878292.1	Chr3	24,500,565	24,501,323	219	24453,40	9,52	53,07	unstable
ZjuLEA-27	LEA_2	XP_015878308.1	Chr3	25,504,871	24,505,816	195	21499,24	10,79	27,75	stable
ZjuLEA-28	LEA_2	XP_015878616.1	Chr3	26,268,493	26,269,876	210	23399,16	9,68	33,21	stable
ZjuLEA-29	LEA_2	XP_015879734.1	Chr4	7,802,571	7,803,783	261	28724,79	9,79	47,13	unstable
ZjuLEA-30	LEA_2	XP_015879927.1	Chr4	8,881,687	8,882,944	264	29014,69	9,65	48,63	unstable
ZjuLEA-31	LEA_2	XP_015880534.1	Chr4	15,484,146	15,485,565	246	27531,54	9,09	46,70	unstable
ZjuLEA-32	LEA_2	XP_015881075.1	Chr4	21,177,722	21,178,279	185	20787,64	9,47	23,22	stable
ZjuLEA-33	LEA_2	XP_015882906.1	Chr5	14,231,262	14,232,352	251	27717,63	9,76	35,89	stable
ZjuLEA-34	LEA_2	XP_015883846.1	Chr5	29,576,091	29,577,480	251	27689,68	9,82	37,45	stable
ZjuLEA-35	LEA_2	XP_015884283.1	Chr6	1,841,515	1,843,369	321	35486,67	10,03	62,89	unstable
ZjuLEA-36	LEA_2	XP_015884414.1	Chr6	2,839,148	2,840,407	269	29399,90	9,95	29,51	stable
ZjuLEA-37	LEA_2	XP_015885407.1	Chr6	9,811,092	9,812,096	256	28849,30	9,48	39,13	stbale
ZjuLEA-38	SMP	XP_015888177.1	Chr7	22,191,905	22,193,143	252	25797,56	4,76	36,97	stable
ZjuLEA-39	LEA_2	XP_015888818.1	Chr8	613,837	615,892	248	27867,81	10,81	45,07	unstable
ZjuLEA-40	LEA_2	XP_015888819.1	Chr8	820,289	821,417	220	24511,92	9,92	38,83	stable
ZjuLEA-41	LEA_2	XP_015888908.1	Chr8	1,526,917	1,529,582	241	26924,63	10,22	47,69	unstable
ZjuLEA-42	LEA_2	XP_015888909.1	Chr8	1,526,917	1,529,582	241	26924,63	10,22	47,69	unstable
ZjuLEA-43	LEA_2	XP_015888911.1	Chr8	1,526,917	1,529,582	203	22212,08	9,98	40,89	unstable
ZjuLEA-44	LEA_2	XP_015888912.1	Chr8	1,526,917	1,529,582	203	22212,08	9,98	40,89	unstable
ZjuLEA-45	LEA_2	XP_015889834.1	Chr8	6,769,735	6,771,377	319	35204,16	10,06	56,79	unstable
ZjuLEA-46	UD	XP_015890004.1	Chr8	7,855,860	7,858,074	379	41861,19	5,06	29,45	stable
ZjuLEA-47	UD	XP_015890005.1	Chr8	7,855,859	7,858,073	376	4149,82	5,11	28,86	stable
ZjuLEA-48	UD	XP_015890006.1	Chr8	7,855,859	7,858,073	363	40194,37	5,09	26,17	stable
ZjuLEA-49	SMP	XP_015891517.1	Chr9	1,713,945	1,715,293	260	26791,51	4,99	30,49	stable
ZjuLEA-50	UD	XP_015891973.1	Chr9	3,941,549	3,943,558	213	23681,82	9,79	42,51	stable
ZjuLEA-51	LEA_2	XP_015894546.1	Chr10	4,494,298	4,496,240	338	38414,09	10,32	57,77	unstable
ZjuLEA-52	LEA_2	XP_015896074.1	Chr11	801,828	803,002	226	23629.44	9,64	42,54	stable

ZjuLEA-53	LEA_2	XP_015896527.1	Chr11	4,190,247	4,191,497	218	24217,21	9,32	36,73	stable
ZjuLEA-54	LEA_2	XP_015896529.1	Chr11	4,185,916	4,186,850	210	23735,71	10,27	40,13	stable
ZjuLEA-55	LEA_5	XP_015897237.1	Crh11	13,796,194	13,797,221	113	12419,55	6,31	51,06	unstable
ZjuLEA-56	LEA_5	XP_015897238.1	Crh11	13,799,892	13,800,595	93	10349,41	6,92	41,95	unstable
ZjuLEA-57	UD	XP_015897483.1	Chr11	15,623,977	15,624,743	201	22395,21	9,21	32,45	stable
ZjuLEA-58	LEA_2	XP_015897772.1	Chr11	18,430,724	18,432,205	201	21448,91	9,75	34,73	stable
ZjuLEA-59	LEA_2	XP_015897785.1	Chr11	18,440,052	18,441,831	209	22946,51	9,95	30,20	stable
ZjuLEA-60	LEA_2	XP_015898307.1	Chr12	2,914,810	2,916,737	264	29491,83	9,75	48,03	unstable
ZjuLEA-61	LEA_2	XP_015898332.1	Chr12	3,213,226	3,215,156	210	23649,38	8,79	43,87	unstable
ZjuLEA-62	LEA_4	XP_015898588.1	Chr12	4,276,914	4,276,766	515	56357,80	5,97	20,71	stable
ZjuLEA-63	LEA_2	XP_015898720.1	Chr12	5,347,957	5,348,598	213	24084,20	9,82	33,51	stable
ZjuLEA-64	LEA_2	XP_015898846.1	Chr12	5,890,140	5,891,156	229	25656,04	9,80	24,07	stable
ZjuLEA-65	LEA_2	XP_015898847.1	Chr12	5,882,530	5,883,566	226	25489,68	9,64	32.78	stable
ZjuLEA-66	LEA_3	XP_015898848.1	Chr12	5,878,305	5,879,570	215	24457,35	9,98	31,54	stable
ZjuLEA-67	LEA_2	XP_015898851.1	Chr12	5,892,852	5,893,687	228	25619,85	9,67	27,42	stable
ZjuLEA-68	LEA_2	XP_015898858.1	Chr12	5,866,601	5,873,228	249	27763,80	9,51	45,00	unstable
ZjuLEA-69	LEA_2	XP_015898859.1	Chr12	5,866,601	5,873,228	249	27763,80	9,51	45,00	unstable
ZjuLEA-70	LEA_1	XP_015898949.1	Chr12	6,825,759	6,827,127	193	19646,19	9,10	15.86	stable
ZjuLEA-71	LEA_3	XP_015899882.1	Chr12	17,537,001	17,537,628	101	10735,18	9,39	47,97	unstable
ZjuLEA-72	LEA_3	XP_015870974.1	NW	425	1,37	253	27427,17	10,27	22,24	stable
ZjuLEA-73	LEA_2	XP_015872420.1	NW	734	1,924	254	29123.07	10,02	35,10	stable
ZjuLEA-74	LEA_3	XP_015870897.1	NW	781	1,768	99	10332,66	9,69	34,03	stable
ZjuLEA-75	LEA_3	XP_015872231.1	NW	986	1,496	103	10811,12	9,63	33,09	stable
ZjuLEA-76	LEA_2	XP_015866337.1	NW	1,663	2,265	200	22079,81	9,81	27.84	stable
ZjuLEA-77	LEA_3	XP_015870749.1	NW	1,758	2,745	99	10332,66	9,69	34,03	stable
ZjuLEA-78	LEA_3	XP_015869267.1	NW	1,769	2,769	99	10332,66	9,69	34,03	stable
ZjuLEA-79	LEA_3	XP_015870734.1	NW	5,818	6,819	99	10332,66	9,69	34,03	stable
ZjuLEA-80	LEA_3	XP_015870652.1	NW	6,055	7,05	99	10332,66	9,69	34,03	stable
ZjuLEA-81	LEA_6	XP_015870785.1	NW	6,177	7,172	99	10332,66	9,69	34,03	stable

ZjuLEA-82	LEA_3	XP_015870582.1	NW	6,44	7,435	99	10332,66	9,69	34,03	stable
ZjuLEA-83	LEA_3	XP_015870569.1	NW	6,443	7,438	99	10332,66	9,69	34,03	stable
ZjuLEA-84	LEA_3	XP_015868932.1	NW	8,513	9,512	99	10332,66	9,69	34,03	stable
ZjuLEA-85	LEA_3	XP_015868536.1	NW	19K	20K	99	10332,66	9,69	34,03	stable
ZjuLEA-86	LEA_2	XP_015867337.1	NW	22K	22K	200	22128,87	9,77	20,01	stable
ZjuLEA-87	LEA_3	XP_015869198.1	NW	23K	24K	99	10332,66	9,69	34,03	stable
ZjuLEA-88	UD	XP_015867416.1	NW	37K	39K	477	52808,53	9,14	38,33	stable
ZjuLEA-89	UD	XP_015867339.1	NW	45K	46K	182	20181,53	9,77	36,07	stable
ZjuLEA-90	UD	XP_015867340.1	NW	49K	49K	182	20223,53	9,78	31,90	stable
ZjuLEA-91	LEA_1	XP_015865991.1	NW	64k	65k	117	12951,86	9,50	36,70	stable
ZjuLEA-92	LEA_6	XP_015901635.1	NW	170K	171K	89	9697,56	5,31	48,74	unstable
ZjuLEA-93	LEA_2	XP_015900439.1	NW	480K	481K	215	24457,35	9,98	31,54	stable

UD: undefined
SMP: seed maturation protein

Supplementary Table S2. Targeted *ZjuLEA* genes and their targeting miRNAs.

miRNA_Acc.	Target_Acc.	Exp.	UPE	miRNA_aligned_fragment	Target_aligned_fragment	Inhibition
ath-miR5998a	ZjuLEA-27	5.0	-1.0	ACAGUUUGUGUUUUGUUUUGU	AAAAAAAAAAAAAAAAACUGA	Translation
ath-miR5998b	ZjuLEA-27	5.0	-1.0	ACAGUUUGUGUUUUGUUUUGU	AAAAAAAAAAAAAAAAACUGA	Translation
ath-miR837-5p	ZjuLEA-27	5.0	-1.0	AUCAGUUUCUUGUUCGUUUCA	AAAAAAAAAAAAAAAACUGAU	Cleavage
ath-miR156d-3p	ZjuLEA-78	5.0	-1.0	GCUCACUCUCUUUUUGUCAUAAC	AAAAAAAGAAGAAGAGAGGGAGC	Cleavage
ath-miR837-5p	ZjuLEA-91	5.0	-1.0	AUCAGUUUCUUGUUCGUUUCA	AAAAAAGCAAAAGAAGCUGAG	Cleavage
ath-miR777	ZjuLEA-06	5.0	-1.0	UACGCAUUGAGUUUCGUUGCUU	AAACGGUGAGACUUGAUUUGUA	Cleavage
ath-miR4243	ZjuLEA-50	5.0	-1.0	UUGAAAUUGUAGAUUUCGUAC	AAACUCGAUCUGUAAUUUAAA	Cleavage
ath-miR837-3p	ZjuLEA-31	5.0	-1.0	AAACGAACAAAAAACUGAUGG	AAAUUAAUUCGUUGUUUGUUU	Translation
ath-miR399c-5p	ZjuLEA-86	5.0	-1.0	GGGCAUCUUUCUAUUGGCAGG	AACGGCAAUGGGAAGAUGACU	Cleavage
ath-miR8165	ZjuLEA-76	5.0	-1.0	AAUGGAGGCAAGUGUGAAGGA	AACUCCACGGUUGCCUUCAGU	Cleavage
ath-miR413	ZjuLEA-21	5.0	-1.0	AUAGUUUCUCUUGUUCUGCAC	AAGAAGAACAAGAAAAACAAA	Cleavage
ath-miR4221	ZjuLEA-70	5.0	-1.0	UUUUCCUCUGUUGAAUUCUUGC	AAGAGUAUUGAAAAGAGGGGAA	Translation
ath-miR158a-5p	ZjuLEA-91	5.0	-1.0	CUUUGUCUACAAUUUUGGAAA	AAGCCAAAGUUGAAGAAAAGG	Cleavage
ath-miR1886.1	ZjuLEA-69	5.0	-1.0	UGAGAGAAGUGAGAUGAAAUC	AAGCUCAAAUCACUUUUCUCA	Cleavage
ath-miR854a	ZjuLEA-79	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR854b	ZjuLEA-79	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR854c	ZjuLEA-79	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR854d	ZjuLEA-79	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR854e	ZjuLEA-79	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR859	ZjuLEA-62	5.0	-1.0	UCUCUCUGUUGUGAAGUCAAA	AAGGAUUAUACAACGGAGAAA	Cleavage
ath-miR773b-3p	ZjuLEA-37	5.0	-1.0	UUUGAUUCCAGCUUUUGUCUC	AAGUUGAAAACUGGAAGCAAA	Cleavage
ath-miR420	ZjuLEA-39	5.0	-1.0	UAAACUAAUCACGGAAAUGCA	AAUAUUUUGGUGGUUAUUUUG	Cleavage
ath-miR163	ZjuLEA-51	5.0	-1.0	UUGAAGAGGACUUGGAACUUCGAU	AAUCAUCCUUGAAGUUCUCUUCAA	Cleavage
ath-miR156g	ZjuLEA-34	5.0	-1.0	CGACAGAAGAGAGUGAGCAC	AAUCUCAUUUUCUUCUGAUG	Cleavage
ath-miR5648-3p	ZjuLEA-06	5.0	-1.0	AUCUGAAGAAAAUAGCGGCAU	AAUCUUUUAUUUUUUUUGGGU	Cleavage
ath-miR822-3p	ZjuLEA-14	5.0	-1.0	UGUGCAAAUGCUUUCUACAGG	AAUGUGAGAAGCGUGUGCAUG	Cleavage
ath-miR779.2	ZjuLEA-45	5.0	-1.0	UGAUUGGAAAUUUCGUUGACU	AAUUAUCAAAAUUAUCAAUUA	Cleavage
ath-miR5998a	ZjuLEA-21	5.0	-1.0	ACAGUUUGUGUUUUGUUUUGU	ACAAGA-AAAACAAAGGCUGU	Cleavage
ath-miR5998b	ZjuLEA-21	5.0	-1.0	ACAGUUUGUGUUUUGUUUUGU	ACAAGA-AAAACAAAGGCUGU	Cleavage
ath-miR399b	ZjuLEA-28	5.0	-1.0	UGCCAAAGGAGAGUUGCCCUG	ACAAGAAGCUCUUCUUUGGCU	Cleavage
ath-miR399c-3p	ZjuLEA-28	5.0	-1.0	UGCCAAAGGAGAGUUGCCCUG	ACAAGAAGCUCUUCUUUGGCU	Cleavage
ath-miR858b	ZjuLEA-31	5.0	-1.0	UUCGUUGUCUGUUCGACCUUG	ACAGCUCGUACGGACGACGCA	Cleavage
ath-miR5653	ZjuLEA-73	5.0	-1.0	UGGGUUGAGUUGAGUUGAGUUGGC	ACAGGCUCAUAUCAACUCAAGCUC	Cleavage
ath-miR5997	ZjuLEA-65	5.0	-1.0	UGAAACCAAGUAGCUAAAUAG	ACAUUUAUUUAUUUGUUUUUU	Cleavage
ath-miR834	ZjuLEA-17	5.0	-1.0	UGGUAGCAGUAGCGGUGGUAA	ACCCUGCUGUUGCUGCUGCCU	Cleavage
ath-miR5014a-5p	ZjuLEA-65	5.0	-1.0	ACACUUAGUUUUGUACAACAU	ACCUUCCAGAAGACUAAGUGU	Cleavage
ath-miR8181	ZjuLEA-45	5.0	-1.0	UGGGGGUGGGGGGGUGACAG	ACGUCACGUCCACACCCCUA	Cleavage
ath-miR826b	ZjuLEA-54	5.0	-1.0	UGGUUUUGGACACGUGAAAAU	AGAAUCCCGUAUUCAAAACCA	Translation

ath-miR414	ZjuLEA-46	5.0	-1.0	UCAUCUUCAUCAUCAUCGUCA	AGACGAUGGAGGUAGGGAUGA	Cleavage
ath-miR4239	ZjuLEA-13	5.0	-1.0	UUUGUUAUUUUCGCAUGCUCC	AGAGCA--CGAGAAUGACAAA	Cleavage
ath-miR2112-5p	ZjuLEA-11	5.0	-1.0	CGCAAAUGCGGAUAUCAAUGU	AGAUUUAUUUAUGCAUUUGUG	Translation
ath-miR5657	ZjuLEA-59	5.0	-1.0	UGGACAAGGUUAGAUUUGGUG	AGCAAGAUUUGGCUUUGUUCC	Cleavage
ath-miR408-5p	ZjuLEA-49	5.0	-1.0	ACAGGGAACAAGCAGAGCAUG	AGCCUUCUGCUUUUUCCCUGG	Cleavage
ath-miR1886.1	ZjuLEA-68	5.0	-1.0	UGAGAGAAGUGAGAUGAAAU	AGCUCAAAUCACUUUUCUCA	Cleavage
ath-miR837-3p	ZjuLEA-09	5.0	-1.0	AAACGAACAAAAAACUGAUGG	AGCUUGGUUUCUUGUUCUUUU	Translation
ath-miR156h	ZjuLEA-92	5.0	-1.0	UGACAGAAGAAAGAGAGCAC	AGGCUAAUUUUUUUUUGUUA	Cleavage
ath-miR414	ZjuLEA-53	5.0	-1.0	UCAUCUUCAUCAUCAUCGUCA	AGGGGAUGAUCAUGAAUAUGG	Translation
ath-miR5997	ZjuLEA-50	5.0	-1.0	UGAAACCAAGUAGCUAAAUAG	AGGUGUAGCUAAUUGGUAUUA	Translation
ath-miR837-3p	ZjuLEA-58	5.0	-1.0	AAACGAACAAAAAACUGAUGG	AGGUUUGGUUUUUGUUUUUUU	Cleavage
ath-miR825	ZjuLEA-71	5.0	-1.0	UUCUCAAGAAGGUGCAUGAAC	AGUUUUCUUUCUUCUUGAGAA	Cleavage
ath-miR857	ZjuLEA-91	5.0	-1.0	UUUUGUAUGUUGAAGGUGUAU	AUACAGUUUUGAUAUAUAUAA	Cleavage
ath-miR834	ZjuLEA-04	5.0	-1.0	UGGUAGCAGUAGCGGUGGUAA	AUACUAUGGCUCCUCCUACCA	Translation
ath-miR156a-5p	ZjuLEA-88	5.0	-1.0	UGACAGAAGAGAGUGAGCAC	AUACUUAUUGUCUUUUGUCC	Translation
ath-miR156b-5p	ZjuLEA-88	5.0	-1.0	UGACAGAAGAGAGUGAGCAC	AUACUUAUUGUCUUUUGUCC	Translation
ath-miR156c-5p	ZjuLEA-88	5.0	-1.0	UGACAGAAGAGAGUGAGCAC	AUACUUAUUGUCUUUUGUCC	Translation
ath-miR156d-5p	ZjuLEA-88	5.0	-1.0	UGACAGAAGAGAGUGAGCAC	AUACUUAUUGUCUUUUGUCC	Translation
ath-miR156e	ZjuLEA-88	5.0	-1.0	UGACAGAAGAGAGUGAGCAC	AUACUUAUUGUCUUUUGUCC	Translation
ath-miR156f-5p	ZjuLEA-88	5.0	-1.0	UGACAGAAGAGAGUGAGCAC	AUACUUAUUGUCUUUUGUCC	Translation
ath-miR156g	ZjuLEA-88	5.0	-1.0	CGACAGAAGAGAGUGAGCAC	AUACUUAUUGUCUUUUGUCC	Translation
ath-miR157d	ZjuLEA-88	5.0	-1.0	UGACAGAAGAUAGAGAGCAC	AUACUUAUUGUCUUUUGUCC	Cleavage
ath-miR5021	ZjuLEA-58	5.0	-1.0	UGAGAAGAAGAAGAAGAAAA	AUAUCUUCUUCUUGUUAUUG	Cleavage
ath-miR843	ZjuLEA-36	5.0	-1.0	UUUAGGUCGAGCUUCAUUGGA	AUCAAAGGGACUCCACCUAAA	Cleavage
ath-miR163	ZjuLEA-07	5.0	-1.0	UUGAAGAGGACUUGGAACUUCGAU	AUCCGAGUUCCCGGUUUCCUUCAG	Cleavage
ath-miR854a	ZjuLEA-29	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AUCCUCGCCGUUGUCCUCGUC	Cleavage
ath-miR854b	ZjuLEA-29	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AUCCUCGCCGUUGUCCUCGUC	Cleavage
ath-miR854c	ZjuLEA-29	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AUCCUCGCCGUUGUCCUCGUC	Cleavage
ath-miR854d	ZjuLEA-29	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AUCCUCGCCGUUGUCCUCGUC	Cleavage
ath-miR854e	ZjuLEA-29	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AUCCUCGCCGUUGUCCUCGUC	Cleavage
ath-miR854a	ZjuLEA-29	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AUCCUCUUCUUUUUUUUUAUU	Cleavage
ath-miR854b	ZjuLEA-29	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AUCCUCUUCUUUUUUUUUAUU	Cleavage
ath-miR854c	ZjuLEA-29	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AUCCUCUUCUUUUUUUUUAUU	Cleavage
ath-miR854d	ZjuLEA-29	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AUCCUCUUCUUUUUUUUUAUU	Cleavage
ath-miR854e	ZjuLEA-29	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AUCCUCUUCUUUUUUUUUAUU	Cleavage
ath-miR5663-3p	ZjuLEA-30	5.0	-1.0	UGAGAAUGCAAAUCCUUAGCU	AUCUAUGGCUUUGUAUUAUUA	Cleavage
ath-miR8181	ZjuLEA-27	5.0	-1.0	UGGGGGUGGGGGGGUGACAG	AUCUCACUCCCCCAUUUUAA	Cleavage
ath-miR5019	ZjuLEA-35	5.0	-1.0	UGUUGGGAAAGAAAAACUCUU	AUGAUUUAUUUAUUCUCAAUA	Translation
ath-miR829-3p.1	ZjuLEA-40	5.0	-1.0	AGCUCUGAUACCAAAUGAUGGAAU	AUGGCAU-GUUUGGGAUUGGAGCU	Translation
ath-miR868-5p	ZjuLEA-62	5.0	-1.0	UCAUGUCGUAAUAGUAGUCAC	AUGGCUUCUAUUUCGUCAUGG	Cleavage

ath-miR5656	ZjuLEA-19	5.0	-1.0	ACUGAAGUAGAGAUUGGGUUU	AUGUUCUAUUUCUAUUUUAGA	Cleavage
ath-miR156d-3p	ZjuLEA-14	5.0	-1.0	GCUCACUCUCUUUUUGUCAUAAC	AUGUUGACGAGAAGUGAUUGAGA	Cleavage
ath-miR415	ZjuLEA-53	5.0	-1.0	AACAGAGCAGAAACAGAACAU	AUGUUUUCCAUUUGCUCUGUU	Cleavage
ath-miR865-3p	ZjuLEA-33	5.0	-1.0	UUUUUCCUCAAAUUUAUCCAA	AUUCAUACUUUUGAGGAAGAA	Cleavage
ath-miR5665	ZjuLEA-08	5.0	-1.0	UUGGUGGACAAGAUCUGGGAU	AUUGCAGAUCUUGUGCAUGAA	Cleavage
ath-miR780.1	ZjuLEA-15	5.0	-1.0	UCUAGCAGCUGUUGAGCAGGU	AUUUGUGCAGGAGCUGCUGGG	Translation
ath-miR870-3p	ZjuLEA-88	5.0	-1.0	UAAUUUGGUGUUUCUUCGAUC	AUUUUAUGAAAAGCCAAGUUA	Translation
ath-miR5641	ZjuLEA-36	5.0	-1.0	UGGAAGAAGAUGAUAGAAUUA	AUUUUCUUUUCUCUUCUUUUA	Translation
ath-miR5022	ZjuLEA-03	5.0	-1.0	GUCAUG-GGGUAUGAUCGAAUG	AUUUUGAUUAUAUUCACAUGAC	Cleavage
ath-miR5628	ZjuLEA-06	5.0	-1.0	GAAAUAGCGAAGAUAUGAUUA	CAAACAUAUCUUUGAUAAUUU	Cleavage
ath-miR5628	ZjuLEA-07	5.0	-1.0	GAAAUAGCGAAGAUAUGAUUA	CAAACAUAUCUUUGAUAAUUU	Cleavage
ath-miR156d-3p	ZjuLEA-74	5.0	-1.0	GCUCACUCUCUUUUUGUCAUAAC	CAAAGGAAAAAAAAAGAGGGAGC	Translation
ath-miR4239	ZjuLEA-49	5.0	-1.0	UUUGUUAUUUUCGCAUGCUCC	CAACCUUGUGAAGAAAACGAA	Cleavage
ath-miR5998a	ZjuLEA-59	5.0	-1.0	ACAGUUUGUGUUUUGUUUUGU	CAAGAGCAAGAC-CAAAUUGU	Cleavage
ath-miR5998b	ZjuLEA-59	5.0	-1.0	ACAGUUUGUGUUUUGUUUUGU	CAAGAGCAAGAC-CAAAUUGU	Cleavage
ath-miR5015	ZjuLEA-67	5.0	-1.0	UUGGUGUUAUGUGUAGUCUUC	CAAGGUUAAAUGUGACGUCAA	Cleavage
ath-miR5663-3p	ZjuLEA-53	5.0	-1.0	UGAGAAUGCAAAUCCUUAGCU	CAAUAGGGACUUGAAUUUUCA	Cleavage
ath-miR823	ZjuLEA-49	5.0	-1.0	UGGGUGGUGAUCAUAUAAGAU	CACUAAUAUGAGUACUACUCC	Translation
ath-miR5998a	ZjuLEA-59	5.0	-1.0	ACAGUUUGUGUUUUGUUUUGU	CAGAAAAGAAAUACAAACUUC	Cleavage
ath-miR5998b	ZjuLEA-59	5.0	-1.0	ACAGUUUGUGUUUUGUUUUGU	CAGAAAAGAAAUACAAACUUC	Cleavage
ath-miR397a	ZjuLEA-29	5.0	-1.0	UCAUUGAGUGCAGCGUUGAUG	CAGAGACGCUUCGCUUAAUGA	Translation
ath-miR157a-3p	ZjuLEA-62	5.0	-1.0	GCUCUCUAGCCUUCUGUCAUC	CAGCCGAGAAGGCUAGAGAGA	Cleavage
ath-miR157b-3p	ZjuLEA-62	5.0	-1.0	GCUCUCUAGCCUUCUGUCAUC	CAGCCGAGAAGGCUAGAGAGA	Cleavage
ath-miR858a	ZjuLEA-31	5.0	-1.0	UUUCGUUGUCUGUUCGACCUU	CAGCUCGUACGGACGACGCAG	Cleavage
ath-miR5642a	ZjuLEA-49	5.0	-1.0	UCUCGCGCUUGUACGGCUUU	CAGGCGGUGUAGGUGCGACA	Cleavage
ath-miR5642b	ZjuLEA-49	5.0	-1.0	UCUCGCGCUUGUACGGCUUU	CAGGCGGUGUAGGUGCGACA	Cleavage
ath-miR4221	ZjuLEA-46	5.0	-1.0	UUUUCCUCUGUUGAAUUCUUGC	CAGGGAGAACAACAAAGGAAGA	Cleavage
ath-miR417	ZjuLEA-59	5.0	-1.0	GAAGGUAGUGAAUUUGUUCGA	CAUAUCACAUUCACUAUCUAC	Cleavage
ath-miR5662	ZjuLEA-66	5.0	-1.0	AGAGGUGACCAUUGGAGAUG	CAUCUCCGGUCGUUACCAUU	Translation
ath-miR5021	ZjuLEA-40	5.0	-1.0	UGAGAAGAAGAAGAAGAAAA	CAUUUUCCUUUUUCUUUGCA	Cleavage
ath-miR837-5p	ZjuLEA-20	5.0	-1.0	AUCAGUUUCUUGUUCGUUUCA	CCAAGCAAACAAGAAGCAAAU	Cleavage
ath-miR5640	ZjuLEA-05	5.0	-1.0	UGAGAGAAGGAAUUAGAUUCA	CCAAUUCAGGUUCUUCUCUCU	Cleavage
ath-miR4245	ZjuLEA-37	5.0	-1.0	ACAAAGUUUUAUACUGACAAU	CCAGUGAGAAUGAAACUUUGG	Cleavage
ath-miR8181	ZjuLEA-22	5.0	-1.0	UGGGGGUGGGGGGGUGACAG	CCAUUACUCCUCCACCACCA	Cleavage
ath-miR5020c	ZjuLEA-72	5.0	-1.0	UGGCAUGGAAGAAGGUGAGAC	CCCUUAACUCUUUCCUUGCCA	Cleavage
ath-miR398a-5p	ZjuLEA-28	5.0	-1.0	AAGGAGUGGCAUGUGAACACA	CCGGUUUGCCUGUUGCUCCUU	Cleavage
ath-miR395a	ZjuLEA-50	5.0	-1.0	CUGAAGUGUUUGGGGGAACUC	CCGUUCACCCAAACUCUCCAC	Cleavage
ath-miR395d	ZjuLEA-50	5.0	-1.0	CUGAAGUGUUUGGGGGAACUC	CCGUUCACCCAAACUCUCCAC	Cleavage
ath-miR395e	ZjuLEA-50	5.0	-1.0	CUGAAGUGUUUGGGGGAACUC	CCGUUCACCCAAACUCUCCAC	Cleavage
ath-miR5658	ZjuLEA-16	5.0	-1.0	AUGAUGAUGAUGAUGAUGAAA	CCUCGUCGUCGUCUUCGUCGG	Cleavage

ath-miR5017-3p	ZjuLEA-14	5.0	-1.0	UUAUACCAAAUUAAUAGCAAA	CCUUCUAGUUGUUUGGUGUAG	Cleavage
ath-miR1886.1	ZjuLEA-28	5.0	-1.0	UGAGAGAAGUGAGAUGAAAUC	CCUUUCUCUUCUCUUCUCUCU	Translation
ath-miR869.1	ZjuLEA-39	5.0	-1.0	AUUGGUUCAAUUCUGGUGUUG	CGAGACC-GAAUUGGGUCAGU	Cleavage
ath-miR417	ZjuLEA-86	5.0	-1.0	GAAGGUAGUGAAUU--UGUUCGA	CGGAACACCAGUUCAUCACCUUC	Cleavage
ath-miR5654-3p	ZjuLEA-60	5.0	-1.0	UGGAAGAUGCUUUGGGAUUUAUU	CGGCAAUUUCAGAUCCUCUUCCG	Translation
ath-miR837-3p	ZjuLEA-54	5.0	-1.0	AAACGAACAAA-AAACUGAUGG	CUAAUAGUUUGUUUGUUUGUUU	Translation
ath-miR774b-5p	ZjuLEA-31	5.0	-1.0	UGAGAUGAAGAUAUGGGUGAU	CUCACCCACAUUUGCAUUUCU	Cleavage
ath-miR167c-3p	ZjuLEA-23	5.0	-1.0	UAGGUCAUGCUGGUAGUUUCACC	CUCGAAGCUACCGCCAUGACCGC	Translation
ath-miR172b-5p	ZjuLEA-08	5.0	-1.0	GCAGCACCAUUAAGAUUCAC	CUGAGUUUUG-UGGUGCUGU	Translation
ath-miR172b-5p	ZjuLEA-08	5.0	-1.0	GCAGCACCAUUAAGAUUCAC	CUGAGUUUUG-UGGUGCUGU	Translation
ath-miR172e-5p	ZjuLEA-08	5.0	-1.0	GCAGCACCAUUAAGAUUCAC	CUGAGUUUUG-UGGUGCUGU	Translation
ath-miR172e-5p	ZjuLEA-08	5.0	-1.0	GCAGCACCAUUAAGAUUCAC	CUGAGUUUUG-UGGUGCUGU	Translation
ath-miR846-5p	ZjuLEA-01	5.0	-1.0	CAUUCAAGGACUUCUAUUCAG	CUGAUGAGAAUUUCUUGGGUG	Translation
ath-miR8181	ZjuLEA-63	5.0	-1.0	UGGGGGUGGGGGGGUGACAG	CUGCCACCCUUGCACCUCCU	Cleavage
ath-miR834	ZjuLEA-04	5.0	-1.0	UGGUAGCAGUAGCGGUGGUAA	CUGCCUCUGCUACAGCUUCCA	Cleavage
ath-miR157a-3p	ZjuLEA-04	5.0	-1.0	GCUCUCU-AGCCUUCUGUCAUC	CUGGACAGAAGGCUCAGAGAGA	Cleavage
ath-miR157b-3p	ZjuLEA-04	5.0	-1.0	GCUCUCU-AGCCUUCUGUCAUC	CUGGACAGAAGGCUCAGAGAGA	Cleavage
ath-miR854a	ZjuLEA-28	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	CUUCUCUUCUCUCUUCUCCUC	Cleavage
ath-miR854b	ZjuLEA-28	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	CUUCUCUUCUCUCUUCUCCUC	Cleavage
ath-miR854c	ZjuLEA-28	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	CUUCUCUUCUCUCUUCUCCUC	Cleavage
ath-miR854d	ZjuLEA-28	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	CUUCUCUUCUCUCUUCUCCUC	Cleavage
ath-miR854e	ZjuLEA-28	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	CUUCUCUUCUCUCUUCUCCUC	Cleavage
ath-miR854a	ZjuLEA-42	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	CUUCUUCUUCUUUUUCUUAUU	Cleavage
ath-miR854b	ZjuLEA-42	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	CUUCUUCUUCUUUUUCUUAUU	Cleavage
ath-miR854c	ZjuLEA-42	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	CUUCUUCUUCUUUUUCUUAUU	Cleavage
ath-miR854d	ZjuLEA-42	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	CUUCUUCUUCUUUUUCUUAUU	Cleavage
ath-miR854e	ZjuLEA-42	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	CUUCUUCUUCUUUUUCUUAUU	Cleavage
ath-miR862-3p	ZjuLEA-06	5.0	-1.0	AUAUGCUGGAUCUACUUGAAG	CUUGAAGUAGCUUGAGCAUGU	Translation
ath-miR862-3p	ZjuLEA-07	5.0	-1.0	AUAUGCUGGAUCUACUUGAAG	CUUGAAGUAGCUUGAGCAUGU	Translation
ath-miR397b	ZjuLEA-45	5.0	-1.0	UCAUUGAGUGCAUCGUUGAUG	CUUGAAUGGUGCACCCAAUCA	Cleavage
ath-miR405a	ZjuLEA-22	5.0	-1.0	AUGAGUUGGGUCUAACCCAUAACU	CUUGAUGGGGUAGAGCUGGCUCAC	Translation
ath-miR405b	ZjuLEA-22	5.0	-1.0	AUGAGUUGGGUCUAACCCAUAACU	CUUGAUGGGGUAGAGCUGGCUCAC	Translation
ath-miR405d	ZjuLEA-22	5.0	-1.0	AUGAGUUGGGUCUAACCCAUAACU	CUUGAUGGGGUAGAGCUGGCUCAC	Translation
ath-miR5014a-3p	ZjuLEA-68	5.0	-1.0	UUGUACAAAUUUAAGUGUACG	CUUGCACAUAAAUUUUUCUAA	Cleavage
ath-miR5014a-3p	ZjuLEA-69	5.0	-1.0	UUGUACAAAUUUAAGUGUACG	CUUGCACAUAAAUUUUUCUAA	Cleavage
ath-miR854b	ZjuLEA-29	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AUCCUCUUCUUUUUUUUUUAUU	Cleavage
ath-miR854c	ZjuLEA-29	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AUCCUCUUCUUUUUUUUUUAUU	Cleavage
ath-miR854d	ZjuLEA-29	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AUCCUCUUCUUUUUUUUUUAUU	Cleavage
ath-miR854e	ZjuLEA-29	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AUCCUCUUCUUUUUUUUUUAUU	Cleavage
ath-miR5663-3p	ZjuLEA-30	5.0	-1.0	UGAGAAUGCAAAUCCUUAGCU	AUCUAUGGCUUUGUAUUAUUA	Cleavage

ath-miR8181	ZjuLEA-27	5.0	-1.0	UGGGGGUGGGGGGGUGACAG	AUCUCACUCCCCCAUUUUAA	Cleavage
ath-miR5019	ZjuLEA-35	5.0	-1.0	UGUUGGGAAAGAAAAACUCUU	AUGAUUUAUUUAUUCUCAAUA	Translation
ath-miR829-3p.1	ZjuLEA-40	5.0	-1.0	AGCUCUGAUACCAAAUGAUGGAAU	AUGGCAU-GUUUGGGAUUGGAGCU	Translation
ath-miR868-5p	ZjuLEA-62	5.0	-1.0	UCAUGUCGUAAUAGUAGUCAC	AUGGCUUCUAUUUCGUCAUGG	Cleavage
ath-miR5656	ZjuLEA-19	5.0	-1.0	ACUGAAGUAGAGAUUGGGUUU	AUGUUCUAUUUCUAUUUUAGA	Cleavage
ath-miR156d-3p	ZjuLEA-14	5.0	-1.0	GCUCACUCUCUUUUUGUCAUAAC	AUGUUGACGAGAAGUGAUUGAGA	Cleavage
ath-miR415	ZjuLEA-53	5.0	-1.0	AACAGAGCAGAAACAGAACAU	AUGUUUUCCAUUUGCUCUGUU	Cleavage
ath-miR865-3p	ZjuLEA-33	5.0	-1.0	UUUUUCCUCAAAUUUAUCCAA	AUUCAUACUUUUGAGGAAGAA	Cleavage
ath-miR865-3p	ZjuLEA-34	5.0	-1.0	UUUUUCCUCAAAUUUAUCCAA	AUUCAUACUUUUGAGGAAGAA	Cleavage
ath-miR5665	ZjuLEA-08	5.0	-1.0	UUGGUGGACAAGAUCUGGGAU	AUUGCAGAUCUUGUGCAUGAA	Cleavage
ath-miR780.1	ZjuLEA-15	5.0	-1.0	UCUAGCAGCUGUUGAGCAGGU	AUUUGUGCAGGAGCUGCUGGG	Translation
ath-miR870-3p	ZjuLEA-88	5.0	-1.0	UAAUUUGGUGUUUCUUCGAUC	AUUUUAUGAAAAGCCAAGUUA	Translation
ath-miR5641	ZjuLEA-36	5.0	-1.0	UGGAAGAAGAUGAUAGAAUUA	AUUUUCUUUUCUCUUCUUUUA	Translation
ath-miR5022	ZjuLEA-03	5.0	-1.0	GUCAUG-GGGUAUGAUCGAAUG	AUUUUGAUUAUAUUCACAUGAC	Cleavage
ath-miR5628	ZjuLEA-06	5.0	-1.0	GAAAUAGCGAAGAUAUGAUUA	CAAACAUAUCUUUGAUAAUUU	Cleavage
ath-miR5628	ZjuLEA-07	5.0	-1.0	GAAAUAGCGAAGAUAUGAUUA	CAAACAUAUCUUUGAUAAUUU	Cleavage
ath-miR156d-3p	ZjuLEA-74	5.0	-1.0	GCUCACUCUCUUUUUGUCAUAAC	CAAAGGAAAAAAAAAGAGGGAGC	Translation
ath-miR5654-3p	ZjuLEA-09	5.0	-1.0	UGGAAGAUGCUUUGGGAUUUAUU	CAACAUUCCCAAAGUACUUUCUC	Cleavage
ath-miR4239	ZjuLEA-49	5.0	-1.0	UUUGUUAUUUUCGCAUGCUCC	CAACCUUGUGAAGAAAACGAA	Cleavage
ath-miR5998a	ZjuLEA-59	5.0	-1.0	ACAGUUUGUGUUUUGUUUUGU	CAAGAGCAAGAC-CAAAUUGU	Cleavage
ath-miR5998b	ZjuLEA-59	5.0	-1.0	ACAGUUUGUGUUUUGUUUUGU	CAAGAGCAAGAC-CAAAUUGU	Cleavage
ath-miR5015	ZjuLEA-67	5.0	-1.0	UUGGUGUUAUGUGUAGUCUUC	CAAGGUUAAAUGUGACGUCAA	Cleavage
ath-miR5663-3p	ZjuLEA-53	5.0	-1.0	UGAGAAUGCAAAUCCUUAGCU	CAAUAGGGACUUGAAUUUUCA	Cleavage
ath-miR823	ZjuLEA-49	5.0	-1.0	UGGGUGGUGAUCAUAUAAGAU	CACUAAUAUGAGUACUACUCC	Translation
ath-miR5998a	ZjuLEA-59	5.0	-1.0	ACAGUUUGUGUUUUGUUUUGU	CAGAAAAGAAAUACAAACUUC	Cleavage
ath-miR5998b	ZjuLEA-59	5.0	-1.0	ACAGUUUGUGUUUUGUUUUGU	CAGAAAAGAAAUACAAACUUC	Cleavage
ath-miR397a	ZjuLEA-29	5.0	-1.0	UCAUUGAGUGCAGCGUUGAUG	CAGAGACGCUUCGCUUAAUGA	Translation
ath-miR157a-3p	ZjuLEA-62	5.0	-1.0	GCUCUCUAGCCUUCUGUCAUC	CAGCCGAGAAGGCUAGAGAGA	Cleavage
ath-miR157b-3p	ZjuLEA-62	5.0	-1.0	GCUCUCUAGCCUUCUGUCAUC	CAGCCGAGAAGGCUAGAGAGA	Cleavage
ath-miR858a	ZjuLEA-31	5.0	-1.0	UUUCGUUGUCUGUUCGACCUU	CAGCUCGUACGGACGACGCAG	Cleavage
ath-miR5642a	ZjuLEA-49	5.0	-1.0	UCUCGCGCUUGUACGGCUUU	CAGGCGGUGUAGGUGCGACA	Cleavage
ath-miR5642b	ZjuLEA-49	5.0	-1.0	UCUCGCGCUUGUACGGCUUU	CAGGCGGUGUAGGUGCGACA	Cleavage
ath-miR4221	ZjuLEA-46	5.0	-1.0	UUUUCCUCUGUUGAAUUCUUGC	CAGGGAGAACAACAAAGGAAGA	Cleavage
ath-miR4221	ZjuLEA-47	5.0	-1.0	UUUUCCUCUGUUGAAUUCUUGC	CAGGGAGAACAACAAAGGAAGA	Cleavage
ath-miR4221	ZjuLEA-48	5.0	-1.0	UUUUCCUCUGUUGAAUUCUUGC	CAGGGAGAACAACAAAGGAAGA	Cleavage
ath-miR417	ZjuLEA-59	5.0	-1.0	GAAGGUAGUGAAUUUGUUCGA	CAUAUCACAUUCACUAUCUAC	Cleavage
ath-miR5662	ZjuLEA-66	5.0	-1.0	AGAGGUGACCAUUGGAGAUG	CAUCUCCGGUCGUUACCAUU	Translation
ath-miR5662	ZjuLEA-93	5.0	-1.0	AGAGGUGACCAUUGGAGAUG	CAUCUCCGGUCGUUACCAUU	Translation
ath-miR5021	ZjuLEA-40	5.0	-1.0	UGAGAAGAAGAAGAAGAAAA	CAUUUUCCUUUUUCUUUGCA	Cleavage
ath-miR837-5p	ZjuLEA-20	5.0	-1.0	AUCAGUUUCUUGUUCGUUUCA	CCAAGCAAACAAGAAGCAAAU	Cleavage

ath-miR5640	ZjuLEA-05	5.0	-1.0	UGAGAGAAGGAAUUAGAUUCA	CCAAUUCAGGUUCUUCUCUCU	Cleavage
ath-miR4245	ZjuLEA-37	5.0	-1.0	ACAAAGUUUUAUACUGACAAU	CCAGUGAGAAUGAAACUUUGG	Cleavage
ath-miR8181	ZjuLEA-22	5.0	-1.0	UGGGGGUGGGGGGGUGACAG	CCAUUACUCCUCCACCACCA	Cleavage
ath-miR5020c	ZjuLEA-72	5.0	-1.0	UGGCAUGGAAGAAGGUGAGAC	CCCUUAACUCUUUCCUUGCCA	Cleavage
ath-miR398a-5p	ZjuLEA-28	5.0	-1.0	AAGGAGUGGCAUGUGAACACA	CCGGUUUGCCUGUUGCUCCUU	Cleavage
ath-miR395a	ZjuLEA-50	5.0	-1.0	CUGAAGUGUUUGGGGGAACUC	CCGUUCACCCAAACUCUCCAC	Cleavage
ath-miR395d	ZjuLEA-50	5.0	-1.0	CUGAAGUGUUUGGGGGAACUC	CCGUUCACCCAAACUCUCCAC	Cleavage
ath-miR395e	ZjuLEA-50	5.0	-1.0	CUGAAGUGUUUGGGGGAACUC	CCGUUCACCCAAACUCUCCAC	Cleavage
ath-miR5658	ZjuLEA-16	5.0	-1.0	AUGAUGAUGAUGAUGAUGAAA	CCUCGUCGUCGUCUUCGUCGG	Cleavage
ath-miR5017-3p	ZjuLEA-14	5.0	-1.0	UUAUACCAAAUUAAUAGCAAA	CCUUCUAGUUGUUUGGUGUAG	Cleavage
ath-miR1886.1	ZjuLEA-28	5.0	-1.0	UGAGAGAAGUGAGAUGAAAUC	CCUUUCUCUUCUCUUCUCUCU	Translation
ath-miR1886.1	ZjuLEA-72	5.0	-1.0	UGAGAGAAGUGAGAUGAAAUC	CCUUUCUUUUCUUUUCUCUUC	Translation
ath-miR401	ZjuLEA-28	5.0	-1.0	CGAAACUGGUGUCGACCGACA	CUUUGGUUGGUACCGGUUUGC	Cleavage
ath-miR403-5p	ZjuLEA-88	5.0	-1.0	UGUUUUGUGCUUGAAUCUAAUU	GAAAAGAUUAAAACACAGAGCA	Translation
ath-miR840-3p	ZjuLEA-19	5.0	-1.0	UUGUUUAGGUCCCUUAGUUUC	GAAACGUGGGGGUCUAAACCA	Cleavage
ath-miR420	ZjuLEA-73	5.0	-1.0	UAAACUAAUCACGGAAAUGCA	GAAAUUUUUGUGAUGAGUUCA	Cleavage
ath-miR5655	ZjuLEA-01	5.0	-1.0	AAGUAGACACAUAAGAAGGAG	GAAUUUCUUGGGUGACUACUU	Translation
ath-miR869.2	ZjuLEA-76	5.0	-1.0	UCUGGUGUUGAGAUAGUUGAC	GACAGCGAGUUCAGCACCGGG	Cleavage
ath-miR5655	ZjuLEA-02	5.0	-1.0	AAGUAGACACAUAAGAAGGAG	GACCACCAUAUGUUUUUACUU	Cleavage
ath-miR2112-3p	ZjuLEA-22	5.0	-1.0	CUUUAUAUCCGCAUUUGCGCA	GACGCGGCUGUGGAUAUCGGG	Cleavage
ath-miR8171	ZjuLEA-59	5.0	-1.0	AUAGGUGGGCCAGUGGUAGGA	GACUGCUACUAGUCCACUCAU	Translation
ath-miR773b-3p	ZjuLEA-73	5.0	-1.0	UUUGAUUCCAGCUUU-UGUCUC	GAGAAACAAGGUUGGAAUCAAU	Cleavage
ath-miR5998a	ZjuLEA-71	5.0	-1.0	ACAGUUUGUGUUUUGUUUUGU	GAGAAACUAAAGGCAAGCUGC	Translation
ath-miR5998b	ZjuLEA-71	5.0	-1.0	ACAGUUUGUGUUUUGUUUUGU	GAGAAACUAAAGGCAAGCUGC	Translation
ath-miR838	ZjuLEA-04	5.0	-1.0	UUUUCUUCUACUUCUUGCACA	GAGGCAA-AAGCAGAAGAGAA	Translation
ath-miR841a-3p	ZjuLEA-49	5.0	-1.0	AUUUCUAGUGGGUCGUAUUCA	GAGGUGAGAGCCACUGGGAAU	Cleavage
ath-miR866-5p	ZjuLEA-33	5.0	-1.0	UCAAGGAACGGAUUUUGUUAA	GAUACAAUAUUUUUUUCUUGA	Cleavage
ath-miR3932a	ZjuLEA-89	5.0	-1.0	AACUUUGUGAUGACAACGAAG	GAUCAUUGUUAUCGCAAUUUU	Cleavage
ath-miR3932b-3p	ZjuLEA-90	5.0	-1.0	AACUUUGUGAUGACAACGAAG	GAUCAUUGUUAUCGCAAUUUU	Cleavage
ath-miR868-3p	ZjuLEA-73	5.0	-1.0	CUUCUUAAGUGCUGAUAAUGC	GCAACACCAGUACCUAAGAAG	Cleavage
ath-miR834	ZjuLEA-15	5.0	-1.0	UGGUAGCAGUAGCGGUGGUAA	GCAACGCUGCUUCUGCUGCUG	Translation
ath-miR5012	ZjuLEA-52	5.0	-1.0	UUUUACUGCUACUUGUGUUCC	GCAAUCUAAGUGGUAAUAAAG	Cleavage
ath-miR5027	ZjuLEA-05	5.0	-1.0	ACCGGUUGGAACUUGCCUUAA	GCAAUGCCAGUUUUAGGCGGU	Cleavage
ath-miR5636	ZjuLEA-49	5.0	-1.0	CGUAGUUGCAGAGCUUGACGG	GCGUCAAUGGCUGCAGCUGCG	Cleavage
ath-miR5645a	ZjuLEA-88	5.0	-1.0	AUUUGAGUCAUGUCGUUAAG	GCUAACGAUAUGGUUCAUAA	Cleavage
ath-miR5645b	ZjuLEA-88	5.0	-1.0	AUUUGAGUCAUGUCGUUAAG	GCUAACGAUAUGGUUCAUAA	Cleavage
ath-miR5645d	ZjuLEA-88	5.0	-1.0	AUUUGAGUCAUGUCGUUAAG	GCUAACGAUAUGGUUCAUAA	Cleavage
ath-miR5645e	ZjuLEA-88	5.0	-1.0	AUUUGAGUCAUGUCGUUAAG	GCUAACGAUAUGGUUCAUAA	Cleavage
ath-miR5645f	ZjuLEA-88	5.0	-1.0	AUUUGAGUCAUGUCGUUAAG	GCUAACGAUAUGGUUCAUAA	Cleavage
ath-miR407	ZjuLEA-21	5.0	-1.0	UUUAAAUCAUAUACUUUUGGU	GCUAAUAGUGUAAGAGUUAAA	Cleavage

ath-miR5022	ZjuLEA-27	5.0	-1.0	GUCAUGGGGUAUGAUCGAAUG	GCUUGGAUCAUAUUACAUGUC	Cleavage
ath-miR773a	ZjuLEA-08	5.0	-1.0	UUUGCUUCCAGCUUUUGUCUC	GGAAAGGAAGCAGGAAGCAGA	Translation
ath-miR162a-5p	ZjuLEA-06	5.0	-1.0	UGGAGGCAGCGGUUCAUCGAUC	GGAAGGUGGACCUCUGCCUUUG	Translation
ath-miR173-5p	ZjuLEA-28	5.0	-1.0	UUCGCUUGCAGAGAGAAAUCAC	GGAAUUUUGCUUUGCAUGUGAU	Cleavage
ath-miR414	ZjuLEA-17	5.0	-1.0	UCAUCUUCAUCAUCAUCGUCA	GGACGAUAACGGUGAAGGUUA	Cleavage
ath-miR8166	ZjuLEA-36	5.0	-1.0	AGAGAGUGUAGAAAGUUUCUCA	GGAGCAGCCGUCUACGUUCUCU	Cleavage
ath-miR862-3p	ZjuLEA-69	5.0	-1.0	AUAUGCUGGAUCUACUUGAAG	GGCCAAAUAGACCCAGCUUAU	Translation
ath-miR8167a	ZjuLEA-15	5.0	-1.0	AGAUGUGGAGAUCGUGGGGAUG	GGCCACCACGAUGUCUCCGUCU	Translation
ath-miR8167b	ZjuLEA-15	5.0	-1.0	AGAUGUGGAGAUCGUGGGGAUG	GGCCACCACGAUGUCUCCGUCU	Translation
ath-miR8167c	ZjuLEA-15	5.0	-1.0	AGAUGUGGAGAUCGUGGGGAUG	GGCCACCACGAUGUCUCCGUCU	Translation
ath-miR8167d	ZjuLEA-15	5.0	-1.0	AGAUGUGGAGAUCGUGGGGAUG	GGCCACCACGAUGUCUCCGUCU	Translation
ath-miR8167e	ZjuLEA-15	5.0	-1.0	AGAUGUGGAGAUCGUGGGGAUG	GGCCACCACGAUGUCUCCGUCU	Translation
ath-miR8167f	ZjuLEA-15	5.0	-1.0	AGAUGUGGAGAUCGUGGGGAUG	GGCCACCACGAUGUCUCCGUCU	Translation
ath-miR3932a	ZjuLEA-86	5.0	-1.0	AACUUUGUGAUGACAACGAAG	GGUCAUUGUUAUCACAGCUUU	Cleavage
ath-miR3932b-3p	ZjuLEA-76	5.0	-1.0	AACUUUGUGAUGACAACGAAG	GGUCAUUGUUAUCACAGCUUU	Cleavage
ath-miR863-3p	ZjuLEA-14	5.0	-1.0	UUGAGAGCAACAAGACAUAAU	GUAAUGAUUUGUUGUUUCCAA	Cleavage
ath-miR5024-5p	ZjuLEA-58	5.0	-1.0	AUGACAAGGCCAAGAUAUAACA	GUACAUAUCUUCUUCUUGUUAU	Translation
ath-miR834	ZjuLEA-91	5.0	-1.0	UGGUAGCAGUAGCGGUGGUAA	GUACCAUGGCCAGUGCUGCCA	Translation
ath-miR5631	ZjuLEA-91	5.0	-1.0	UGGCAGGAAAGACAUAAUUUU	GUAGUUUUGUUCUUCUUGCCU	Translation
ath-miR1886.1	ZjuLEA-30	5.0	-1.0	UGAGAGAAGUGAGAUGAAAUC	GUAUUGAUUUUAUUUUUUUUA	Cleavage
ath-miR5021	ZjuLEA-29	5.0	-1.0	UGAGAAGAAGAAGAAGAAAA	GUCUCUUCCUCCUCUUCUCC	Cleavage
ath-miR171a-3p	ZjuLEA-23	5.0	-1.0	UGAUUGAGCCGCGCCAAUAUC	GUGGCCGCCGCGGCUCAAUCA	Cleavage
ath-miR4221	ZjuLEA-28	5.0	-1.0	UUUUCCUCUGUUGAAUUCUUGC	GUUAAGAUUCCAAAGAGGAGAA	Translation
ath-miR5020a	ZjuLEA-70	5.0	-1.0	UGGAAGAAGGUGAGACUUGCA	GUUAGGUUUCGUCGUUUUUCA	Cleavage
ath-miR5017-3p	ZjuLEA-58	5.0	-1.0	UUAUACCAAAUUAAUAGCAAA	GUUGUUAUUA-UUUGGUAGAA	Translation
ath-miR172d-5p	ZjuLEA-28	5.0	-1.0	GCAACAUCUUCAAGAUUCAGA	GUUUAAUUUUGAGAGUGUUGG	Cleavage
ath-miR5648-5p	ZjuLEA-39	5.0	-1.0	UUUGGAAAUAUUUGGCUUGACU	GUUUCAGCCGAAUAUUUUCAUU	Cleavage
ath-miR5021	ZjuLEA-09	5.0	-1.0	UGAGAAGAAGAAGAAGAAAA	GUUUCUUGUUCUUUUACUUC	Cleavage
ath-miR156j	ZjuLEA-06	5.0	-1.0	UGACAGAAGAGAGAGAGCAC	GUUUUCUCUCUCUUUUUUUU	Cleavage
ath-miR858b	ZjuLEA-56	5.0	-1.0	UUCGUUGUCUGUUCGACCUUG	UAAAGGAGGACAGACAAGGAA	Cleavage
ath-miR857	ZjuLEA-65	5.0	-1.0	UUUUGUAUGUUGAAGGUGUAU	UAACGACUUUAACGAGCAGAA	Cleavage
ath-miR447a-3p	ZjuLEA-32	5.0	-1.0	UUGGGGACGAGAUGUUUUGUUG	UAAUAAAACUUUUCGUCCUGGA	Cleavage
ath-miR447b	ZjuLEA-32	5.0	-1.0	UUGGGGACGAGAUGUUUUGUUG	UAAUAAAACUUUUCGUCCUGGA	Cleavage
ath-miR837-5p	ZjuLEA-09	5.0	-1.0	AUCAGUUUCUUGUUCGUUUCA	UACAAUGUGCAAGAAGCUGCU	Cleavage
ath-miR5023	ZjuLEA-11	5.0	-1.0	AUUGGUAGUGGAUAAGGGGGC	UACACUUUAUCUGCUCCUGAU	Cleavage
ath-miR156d-3p	ZjuLEA-60	5.0	-1.0	GCUCACUCUCUUUUUGUCAUAAC	UAGAUGAGAGAGAGAGAGGGGGG	Cleavage
ath-miR156h	ZjuLEA-52	5.0	-1.0	UGACAGAAGAAAGAGAGCAC	UAGUUUUUUUUUUUUUGGCA	Cleavage
ath-miR4245	ZjuLEA-51	5.0	-1.0	ACAAAGUUUUAUACUGACAAU	UAUUUUUGUAUAAAAAUUUGA	Cleavage
ath-miR172d-5p	ZjuLEA-25	5.0	-1.0	GCAACAUCUUCAAGAUUCAGA	UCAAAAUCUUGAAGGUGUUCA	Cleavage
ath-miR842	ZjuLEA-26	5.0	-1.0	UCAUGGUCAGAUCCGUCAUCC	UCAUGGUGGUUCUGAUCGUAA	Cleavage

ath-miR5648-3p	ZjuLEA-73	5.0	-1.0	AUCUGAAGAAAAUAGCGGCAU	UCCUCCUUAUUUUCUUUGGAA	Cleavage
ath-miR396b-3p	ZjuLEA-36	5.0	-1.0	GCUCAAGAAAGCUGUGGGAAA	UCGAUCCCAGCUUUCUUCAGC	Cleavage
ath-miR8121	ZjuLEA-29	5.0	-1.0	AAAGUAUAAUGGUUUAGUGGUUUG	UCGUAAAAUUAACCAUUUUAUUUU	Cleavage
ath-miR778	ZjuLEA-41	5.0	-1.0	UGGCUUGGUUUAUGUACACCG	UCUCCUACAGGAACCAAGCCA	Cleavage
ath-miR157d	ZjuLEA-07	5.0	-1.0	UGACAGAAGAUAGAGAGCAC	UCUCUUUUUGUCAUCUGUCA	Cleavage
ath-miR157a-5p	ZjuLEA-06	5.0	-1.0	UUGACAGAAGAUAGAGAGCAC	UCUCUUUUUGUCAUCUGUCAU	Cleavage
ath-miR157b-5p	ZjuLEA-07	5.0	-1.0	UUGACAGAAGAUAGAGAGCAC	UCUCUUUUUGUCAUCUGUCAU	Cleavage
ath-miR157c-5p	ZjuLEA-06	5.0	-1.0	UUGACAGAAGAUAGAGAGCAC	UCUCUUUUUGUCAUCUGUCAU	Cleavage
ath-miR171b-3p	ZjuLEA-62	5.0	-1.0	UUGAGCCGUGCCAAUAUCACG	UCUGCUACUGGUGCUGCUCGA	Cleavage
ath-miR171c-3p	ZjuLEA-62	5.0	-1.0	UUGAGCCGUGCCAAUAUCACG	UCUGCUACUGGUGCUGCUCGA	Cleavage
ath-miR397a	ZjuLEA-65	5.0	-1.0	UCAUUGAGUGCAGCGUUGAUG	UCUUAGCGUUGCAUUUGAAGG	Cleavage
ath-miR837-5p	ZjuLEA-06	5.0	-1.0	AUCAGUUUCUUGUUCGUUUCA	UGAAAGGAAUAAGAGAAUGCU	Cleavage
ath-miR837-5p	ZjuLEA-07	5.0	-1.0	AUCAGUUUCUUGUUCGUUUCA	UGAAAGGAAUAAGAGAAUGCU	Cleavage
ath-miR156a-3p	ZjuLEA-60	5.0	-1.0	GCUCACUGCUCUUUCUGUCAGA	UGAGAGAGAGAGAGGGGGGAGC	Cleavage
ath-miR2938	ZjuLEA-06	5.0	-1.0	GAUCUUUUGAGAGGGUUCCAG	UGCAUAUUCUUUCAAAAGGUC	Cleavage
ath-miR777	ZjuLEA-50	5.0	-1.0	UACGCAUUGAGUUUCGUUGCUU	UGGCAGGUAAACUCGAUCUGUA	Cleavage
ath-miR835-5p	ZjuLEA-42	5.0	-1.0	UUCUUGCAUAUGUU--CUUUAUC	UGUAAAGUCGAUAUAUGAAAGAA	Cleavage
ath-miR5658	ZjuLEA-01	5.0	-1.0	AUGAUGAUGAUGAUGAUGAAA	UGUCACUAUCAUUUUCUUCAU	Cleavage
ath-miR870-3p	ZjuLEA-53	5.0	-1.0	UAAUUUGGUGUUUCUUCGAUC	UGUUGUCCAAAUACUGAAUUA	Cleavage
ath-miR397a	ZjuLEA-65	5.0	-1.0	UCAUUGAGUGCAGCGUUGAUG	UUACAACCUUGCUCUCAAUGC	Cleavage
ath-miR834	ZjuLEA-40	5.0	-1.0	UGGUAGCAGUAGCGGUGGUAA	UUACCAGCGGCACUGCUGCUA	Translation
ath-miR833a-5p	ZjuLEA-40	5.0	-1.0	UGUUUGUUGUACUCGGUCUAGU	UUAUGAACGAGUAUAGCAAGUU	Cleavage
ath-miR865-5p	ZjuLEA-18	5.0	-1.0	AUGAAUUUGGAUCUAAUUGAG	UUCAAUGUGACCCGGAUUCGU	Translation
ath-miR829-5p	ZjuLEA-33	5.0	-1.0	ACUUUGAAGCUUUGAUUUGAA	UUCAGAAUGAAGCUUUAAGUU	Cleavage
ath-miR776	ZjuLEA-50	5.0	-1.0	UCUAAGUCUUCUAUUGAUGUU	UUCAUCCGUGGAAGUCUUCGA	Cleavage
ath-miR156a-3p	ZjuLEA-05	5.0	-1.0	GCUCACUGCUCUUUCUGUCAGA	UUCCAUGGAAAAAGCAAUGAGC	Translation
ath-miR854a	ZjuLEA-30	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	UUCCUCAUCAUUGUCGUCAUC	Cleavage
ath-miR854b	ZjuLEA-30	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	UUCCUCAUCAUUGUCGUCAUC	Cleavage
ath-miR854c	ZjuLEA-30	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	UUCCUCAUCAUUGUCGUCAUC	Cleavage
ath-miR854d	ZjuLEA-30	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	UUCCUCAUCAUUGUCGUCAUC	Cleavage
ath-miR854e	ZjuLEA-30	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	UUCCUCAUCAUUGUCGUCAUC	Cleavage
ath-miR156i	ZjuLEA-35	5.0	-1.0	UGACAGAAGAGAGAGAGCAG	UUCCUUUCUUUAUUUUGUCC	Cleavage
ath-miR156j	ZjuLEA-35	5.0	-1.0	UGACAGAAGAGAGAGAGCAC	UUCCUUUCUUUAUUUUGUCC	Cleavage
ath-miR156g	ZjuLEA-88	5.0	-1.0	CGACAGAAGAGAGUGAGCAC	UUCUUCUUCUUCUUCUGUCG	Cleavage
ath-miR2934-5p	ZjuLEA-21	5.0	-1.0	UCUUUCUGCAAACGCCUUGGA	UUGAAGGUGUUUUGGGAAAGA	Cleavage
ath-miR855	ZjuLEA-35	5.0	-1.0	AGCAAAAGCUAAGGAAAAGGAA	UUGCUAUUUCCUCGCUUUUGUU	Translation
ath-miR846-3p	ZjuLEA-33	5.0	-1.0	UUGAAUUGAAGUGCUUGAAUU	UUGUAAAGCUUUUCAAUUCAU	Cleavage
ath-miR156h	ZjuLEA-58	5.0	-1.0	UGACAGAAGAAAGAGAGCAC	UUGUUUUUUUUUUUUUUUCU	Cleavage
ath-miR156b-3p	ZjuLEA-28	5.0	-1.0	UGCUCACCUCUCUUUCUGUCAGU	UUUAACUGACAGAGAGGUAAUCA	Cleavage
ath-miR824-3p	ZjuLEA-20	5.0	-1.0	CCUUCUCAUCGAUGGUCUAGA	UUUACACCGUCGAUGAGGGUU	Cleavage

ath-miR5021	ZjuLEA-52	5.0	-1.0	UGAGAAGAAGAAGAAGAAAA	UUUUAGUUUUUUUUUUUUUG	Cleavage
ath-miR5021	ZjuLEA-39	5.0	-1.0	UGAGAAGAAGAAGAAGAAAA	UUUUAUUUUUUGUUUUUUUA	Cleavage
ath-miR835-3p	ZjuLEA-40	5.0	-1.0	UGGAGAAGAUACGCAAGAAAG	UUUUCUUUUUUAUUUUCUUCU	Cleavage
ath-miR1886.1	ZjuLEA-54	5.0	-1.0	UGAGAGAAGUGAGAUGAAAUC	UUUUUCUUUUUCUUUUUUUCA	Translation
ath-miR5655	ZjuLEA-01	5.0	-1.0	AAGUAGACACAUAAGAAGGAG	GAAUUUCUUGGGUGACUACUU	Translation
ath-miR5658	ZjuLEA-01	5.0	-1.0	AUGAUGAUGAUGAUGAUGAAA	UGUCACUAUCAUUUUCUUCAU	Cleavage
ath-miR846-5p	ZjuLEA-01	5.0	-1.0	CAUUCAAGGACUUCUAUUCAG	CUGAUGAGAAUUUCUUGGGUG	Translation
ath-miR5655	ZjuLEA-02	5.0	-1.0	AAGUAGACACAUAAGAAGGAG	GACCACCAUAUGUUUUUACUU	Cleavage
ath-miR5022	ZjuLEA-03	5.0	-1.0	GUCAUG-GGGUAUGAUCGAAUG	AUUUUGAUUAUAUUCACAUGAC	Cleavage
ath-miR5654-3p	ZjuLEA-03	5.0	-1.0	UGGAAGAUGCUUUGGGAUUUAUU	GAUGGAAGACAAAGCAUCAUCCA	Cleavage
ath-miR157a-3p	ZjuLEA-04	5.0	-1.0	GCUCUCU-AGCCUUCUGUCAUC	CUGGACAGAAGGCUCAGAGAGA	Cleavage
ath-miR157b-3p	ZjuLEA-04	5.0	-1.0	GCUCUCU-AGCCUUCUGUCAUC	CUGGACAGAAGGCUCAGAGAGA	Cleavage
ath-miR834	ZjuLEA-04	5.0	-1.0	UGGUAGCAGUAGCGGUGGUAA	CUGCCUCUGCUACAGCUUCCA	Cleavage
ath-miR834	ZjuLEA-04	5.0	-1.0	UGGUAGCAGUAGCGGUGGUAA	AUACUAUGGCUCCUCCUACCA	Translation
ath-miR838	ZjuLEA-04	5.0	-1.0	UUUUCUUCUACUUCUUGCACA	GAGGCAA-AAGCAGAAGAGAA	Translation
ath-miR156a-3p	ZjuLEA-05	5.0	-1.0	GCUCACUGCUCUUUCUGUCAGA	UUCCAUGGAAAAAGCAAUGAGC	Translation
ath-miR5027	ZjuLEA-05	5.0	-1.0	ACCGGUUGGAACUUGCCUUAA	GCAAUGCCAGUUUUAGGCGGU	Cleavage
ath-miR5640	ZjuLEA-05	5.0	-1.0	UGAGAGAAGGAAUUAGAUUCA	CCAAUUCAGGUUCUUCUCUCU	Cleavage
ath-miR156i	ZjuLEA-06	5.0	-1.0	UGACAGAAGAGAGAGAGCAG	UUUCUCUCUCUUUUUUUUUU	Cleavage
ath-miR156j	ZjuLEA-06	5.0	-1.0	UGACAGAAGAGAGAGAGCAC	GUUUUCUCUCUCUUUUUUUU	Cleavage
ath-miR157a-5p	ZjuLEA-06	5.0	-1.0	UUGACAGAAGAUAGAGAGCAC	UCUCUUUUUGUCAUCUGUCAU	Cleavage
ath-miR157b-5p	ZjuLEA-06	5.0	-1.0	UUGACAGAAGAUAGAGAGCAC	UCUCUUUUUGUCAUCUGUCAU	Cleavage
ath-miR157c-5p	ZjuLEA-06	5.0	-1.0	UUGACAGAAGAUAGAGAGCAC	UCUCUUUUUGUCAUCUGUCAU	Cleavage
ath-miR157d	ZjuLEA-06	5.0	-1.0	UGACAGAAGAUAGAGAGCAC	UCUCUUUUUGUCAUCUGUCA	Cleavage
ath-miR162a-5p	ZjuLEA-06	5.0	-1.0	UGGAGGCAGCGGUUCAUCGAUC	GGAAGGUGGACCUCUGCCUUUG	Translation
ath-miR162b-5p	ZjuLEA-06	5.0	-1.0	UGGAGGCAGCGGUUCAUCGAUC	GGAAGGUGGACCUCUGCCUUUG	Translation
ath-miR163	ZjuLEA-06	5.0	-1.0	UUGAAGAGGACUUGGAACUUCGAU	AUCCGAGUUCCCGGUUUCCUUCAG	Cleavage
ath-miR2938	ZjuLEA-06	5.0	-1.0	GAUCUUUUGAGAGGGUUCCAG	UGCAUAUUCUUUCAAAAGGUC	Cleavage
ath-miR5628	ZjuLEA-06	5.0	-1.0	GAAAUAGCGAAGAUAUGAUUA	CAAACAUAUCUUUGAUAAUUU	Cleavage
ath-miR5648-3p	ZjuLEA-06	5.0	-1.0	AUCUGAAGAAAAUAGCGGCAU	AAUCUUUUAUUUUUUUUGGGU	Cleavage
ath-miR777	ZjuLEA-06	5.0	-1.0	UACGCAUUGAGUUUCGUUGCUU	AAACGGUGAGACUUGAUUUGUA	Cleavage
ath-miR837-5p	ZjuLEA-06	5.0	-1.0	AUCAGUUUCUUGUUCGUUUCA	UGAAAGGAAUAAGAGAAUGCU	Cleavage
ath-miR862-3p	ZjuLEA-06	5.0	-1.0	AUAUGCUGGAUCUACUUGAAG	CUUGAAGUAGCUUGAGCAUGU	Translation
ath-miR156i	ZjuLEA-07	5.0	-1.0	UGACAGAAGAGAGAGAGCAG	UUUCUCUCUCUUUUUUUUUU	Cleavage
ath-miR156j	ZjuLEA-07	5.0	-1.0	UGACAGAAGAGAGAGAGCAC	GUUUUCUCUCUCUUUUUUUU	Cleavage
ath-miR157a-5p	ZjuLEA-07	5.0	-1.0	UUGACAGAAGAUAGAGAGCAC	UCUCUUUUUGUCAUCUGUCAU	Cleavage
ath-miR157b-5p	ZjuLEA-07	5.0	-1.0	UUGACAGAAGAUAGAGAGCAC	UCUCUUUUUGUCAUCUGUCAU	Cleavage
ath-miR157c-5p	ZjuLEA-07	5.0	-1.0	UUGACAGAAGAUAGAGAGCAC	UCUCUUUUUGUCAUCUGUCAU	Cleavage
ath-miR157d	ZjuLEA-07	5.0	-1.0	UGACAGAAGAUAGAGAGCAC	UCUCUUUUUGUCAUCUGUCA	Cleavage
ath-miR162a-5p	ZjuLEA-07	5.0	-1.0	UGGAGGCAGCGGUUCAUCGAUC	GGAAGGUGGACCUCUGCCUUUG	Translation

ath-miR162b-5p	ZjuLEA-07	5.0	-1.0	UGGAGGCAGCGGUUCAUCGAUC	GGAAGGUGGACCUCUGCCUUUG	Translation
ath-miR163	ZjuLEA-07	5.0	-1.0	UUGAAGAGGACUUGGAACUUCGAU	AUCCGAGUUCCCGGUUUCCUUCAG	Cleavage
ath-miR2938	ZjuLEA-07	5.0	-1.0	GAUCUUUUGAGAGGGUUCCAG	UGCAUAUUCUUUCAAAAGGUC	Cleavage
ath-miR5628	ZjuLEA-07	5.0	-1.0	GAAAUAGCGAAGAUAUGAUUA	CAAACAUAUCUUUGAUAAUUU	Cleavage
ath-miR5648-3p	ZjuLEA-07	5.0	-1.0	AUCUGAAGAAAAUAGCGGCAU	AAUCUUUUAUUUUUUUUGGGU	Cleavage
ath-miR777	ZjuLEA-07	5.0	-1.0	UACGCAUUGAGUUUCGUUGCUU	AAACGGUGAGACUUGAUUUGUA	Cleavage
ath-miR837-5p	ZjuLEA-07	5.0	-1.0	AUCAGUUUCUUGUUCGUUUCA	UGAAAGGAAUAAGAGAAUGCU	Cleavage
ath-miR862-3p	ZjuLEA-07	5.0	-1.0	AUAUGCUGGAUCUACUUGAAG	CUUGAAGUAGCUUGAGCAUGU	Translation
ath-miR172b-5p	ZjuLEA-08	5.0	-1.0	GCAGCACCAUUAAGAUUCAC	CUGAGUUUUG-UGGUGCUGU	Translation
ath-miR172b-5p	ZjuLEA-08	5.0	-1.0	GCAGCACCAUUAAGAUUCAC	CUGAGUUUUG-UGGUGCUGU	Translation
ath-miR172e-5p	ZjuLEA-08	5.0	-1.0	GCAGCACCAUUAAGAUUCAC	CUGAGUUUUG-UGGUGCUGU	Translation
ath-miR172e-5p	ZjuLEA-08	5.0	-1.0	GCAGCACCAUUAAGAUUCAC	CUGAGUUUUG-UGGUGCUGU	Translation
ath-miR5665	ZjuLEA-08	5.0	-1.0	UUGGUGGACAAGAUCUGGGAU	AUUGCAGAUCUUGUGCAUGAA	Cleavage
ath-miR773a	ZjuLEA-08	5.0	-1.0	UUUGCUUCCAGCUUUUGUCUC	GGAAAGGAAGCAGGAAGCAGA	Translation
ath-miR773a	ZjuLEA-08	5.0	-1.0	UUUGCUUCCAGCUUUUGUCUC	GGAAAGGAAGCAGGAAGCAGA	Translation
ath-miR5021	ZjuLEA-09	5.0	-1.0	UGAGAAGAAGAAGAAGAAAA	GUUUCUUGUUCUUUUACUUC	Cleavage
ath-miR5654-3p	ZjuLEA-09	5.0	-1.0	UGGAAGAUGCUUUGGGAUUUAUU	CAACAUUCCCAAAGUACUUUCUC	Cleavage
ath-miR837-3p	ZjuLEA-09	5.0	-1.0	AAACGAACAAAAAACUGAUGG	AGCUUGGUUUCUUGUUCUUUU	Translation
ath-miR837-5p	ZjuLEA-09	5.0	-1.0	AUCAGUUUCUUGUUCGUUUCA	UACAAUGUGCAAGAAGCUGCU	Cleavage
ath-miR2112-5p	ZjuLEA-10	5.0	-1.0	CGCAAAUGCGGAUAUCAAUGU	AGAUUUAUUUAUGCAUUUGUG	Translation
ath-miR4239	ZjuLEA-10	5.0	-1.0	UUUGUUAUUUUCGCAUGCUCC	AGAGCA--CGAGAAUGACAAA	Cleavage
ath-miR5023	ZjuLEA-10	5.0	-1.0	AUUGGUAGUGGAUAAGGGGGC	UACACUUUAUCUGCUCCUGAU	Cleavage
ath-miR2112-5p	ZjuLEA-11	5.0	-1.0	CGCAAAUGCGGAUAUCAAUGU	AGAUUUAUUUAUGCAUUUGUG	Translation
ath-miR4239	ZjuLEA-11	5.0	-1.0	UUUGUUAUUUUCGCAUGCUCC	AGAGCA--CGAGAAUGACAAA	Cleavage
ath-miR5023	ZjuLEA-11	5.0	-1.0	AUUGGUAGUGGAUAAGGGGGC	UACACUUUAUCUGCUCCUGAU	Cleavage
ath-miR2112-5p	ZjuLEA-12	5.0	-1.0	CGCAAAUGCGGAUAUCAAUGU	AGAUUUAUUUAUGCAUUUGUG	Translation
ath-miR4239	ZjuLEA-12	5.0	-1.0	UUUGUUAUUUUCGCAUGCUCC	AGAGCA--CGAGAAUGACAAA	Cleavage
ath-miR5023	ZjuLEA-12	5.0	-1.0	AUUGGUAGUGGAUAAGGGGGC	UACACUUUAUCUGCUCCUGAU	Cleavage
ath-miR2112-5p	ZjuLEA-13	5.0	-1.0	CGCAAAUGCGGAUAUCAAUGU	AGAUUUAUUUAUGCAUUUGUG	Translation
ath-miR4239	ZjuLEA-13	5.0	-1.0	UUUGUUAUUUUCGCAUGCUCC	AGAGCA--CGAGAAUGACAAA	Cleavage
ath-miR5023	ZjuLEA-13	5.0	-1.0	AUUGGUAGUGGAUAAGGGGGC	UACACUUUAUCUGCUCCUGAU	Cleavage
ath-miR156d-3p	ZjuLEA-14	5.0	-1.0	GCUCACUCUCUUUUUGUCAUAAC	AUGUUGACGAGAAGUGAUUGAGA	Cleavage
ath-miR5017-3p	ZjuLEA-14	5.0	-1.0	UUAUACCAAAUUAAUAGCAAA	CCUUCUAGUUGUUUGGUGUAG	Cleavage
ath-miR5654-3p	ZjuLEA-14	5.0	-1.0	UGGAAGAUGCUUUGGGAUUUAUU	UUUCUAUCACAAAGUUUUUUCCG	Cleavage
ath-miR822-3p	ZjuLEA-14	5.0	-1.0	UGUGCAAAUGCUUUCUACAGG	AAUGUGAGAAGCGUGUGCAUG	Cleavage
ath-miR863-3p	ZjuLEA-14	5.0	-1.0	UUGAGAGCAACAAGACAUAAU	GUAAUGAUUUGUUGUUUCCAA	Cleavage
ath-miR780.1	ZjuLEA-15	5.0	-1.0	UCUAGCAGCUGUUGAGCAGGU	AUUUGUGCAGGAGCUGCUGGG	Translation
ath-miR8167a	ZjuLEA-15	5.0	-1.0	AGAUGUGGAGAUCGUGGGGAUG	GGCCACCACGAUGUCUCCGUCU	Translation
ath-miR8167b	ZjuLEA-15	5.0	-1.0	AGAUGUGGAGAUCGUGGGGAUG	GGCCACCACGAUGUCUCCGUCU	Translation
ath-miR8167c	ZjuLEA-15	5.0	-1.0	AGAUGUGGAGAUCGUGGGGAUG	GGCCACCACGAUGUCUCCGUCU	Translation

ath-miR8167d	ZjuLEA-15	5.0	-1.0	AGAUGUGGAGAUCGUGGGGAUG	GGCCACCACGAUGUCUCCGUCU	Translation
ath-miR8167e	ZjuLEA-15	5.0	-1.0	AGAUGUGGAGAUCGUGGGGAUG	GGCCACCACGAUGUCUCCGUCU	Translation
ath-miR8167f	ZjuLEA-15	5.0	-1.0	AGAUGUGGAGAUCGUGGGGAUG	GGCCACCACGAUGUCUCCGUCU	Translation
ath-miR834	ZjuLEA-15	5.0	-1.0	UGGUAGCAGUAGCGGUGGUAA	GCAACGCUGCUUCUGCUGCUG	Translation
ath-miR414	ZjuLEA-16	5.0	-1.0	UCAUCUUCAUCAUCAUCGUCA	GGACGAUAACGGUGAAGGUUA	Cleavage
ath-miR5658	ZjuLEA-16	5.0	-1.0	AUGAUGAUGAUGAUGAUGAAA	CCUCGUCGUCGUCUUCGUCGG	Cleavage
ath-miR834	ZjuLEA-16	5.0	-1.0	UGGUAGCAGUAGCGGUGGUAA	ACCCUGCUGUUGCUGCUGCCU	Cleavage
ath-miR414	ZjuLEA-17	5.0	-1.0	UCAUCUUCAUCAUCAUCGUCA	GGACGAUAACGGUGAAGGUUA	Cleavage
ath-miR5658	ZjuLEA-17	5.0	-1.0	AUGAUGAUGAUGAUGAUGAAA	CCUCGUCGUCGUCUUCGUCGG	Cleavage
ath-miR834	ZjuLEA-17	5.0	-1.0	UGGUAGCAGUAGCGGUGGUAA	ACCCUGCUGUUGCUGCUGCCU	Cleavage
ath-miR393b-3p	ZjuLEA-18	5.0	-1.0	AUCAUGCGAUCUCUUUGGAUU	UUUGUGAUGAGAUCGUAUAAU	Cleavage
ath-miR865-5p	ZjuLEA-18	5.0	-1.0	AUGAAUUUGGAUCUAAUUGAG	UUCAAUGUGACCCGGAUUCGU	Translation
ath-miR5656	ZjuLEA-19	5.0	-1.0	ACUGAAGUAGAGAUUGGGUUU	AUGUUCUAUUUCUAUUUUAGA	Cleavage
ath-miR8171	ZjuLEA-19	5.0	-1.0	AUAGGUGGGCCAGUGGUAGGA	UCUGAACUCUGGUCCAUUUAU	Cleavage
ath-miR840-3p	ZjuLEA-19	5.0	-1.0	UUGUUUAGGUCCCUUAGUUUC	GAAACGUGGGGGUCUAAACCA	Cleavage
ath-miR824-3p	ZjuLEA-20	5.0	-1.0	CCUUCUCAUCGAUGGUCUAGA	UUUACACCGUCGAUGAGGGUU	Cleavage
ath-miR837-5p	ZjuLEA-20	5.0	-1.0	AUCAGUUUCUUGUUCGUUUCA	CCAAGCAAACAAGAAGCAAAU	Cleavage
ath-miR2934-5p	ZjuLEA-21	5.0	-1.0	UCUUUCUGCAAACGCCUUGGA	UUGAAGGUGUUUUGGGAAAGA	Cleavage
ath-miR407	ZjuLEA-21	5.0	-1.0	UUUAAAUCAUAUACUUUUGGU	GCUAAUAGUGUAAGAGUUAAA	Cleavage
ath-miR413	ZjuLEA-21	5.0	-1.0	AUAGUUUCUCUUGUUCUGCAC	AAGAAGAACAAGAAAAACAAA	Cleavage
ath-miR5998a	ZjuLEA-21	5.0	-1.0	ACAGUUUGUGUUUUGUUUUGU	ACAAGA-AAAACAAAGGCUGU	Cleavage
ath-miR5998b	ZjuLEA-21	5.0	-1.0	ACAGUUUGUGUUUUGUUUUGU	ACAAGA-AAAACAAAGGCUGU	Cleavage
ath-miR2112-3p	ZjuLEA-22	5.0	-1.0	CUUUAUAUCCGCAUUUGCGCA	GACGCGGCUGUGGAUAUCGGG	Cleavage
ath-miR405a	ZjuLEA-22	5.0	-1.0	AUGAGUUGGGUCUAACCCAUAACU	CUUGAUGGGGUAGAGCUGGCUCAC	Translation
ath-miR405b	ZjuLEA-22	5.0	-1.0	AUGAGUUGGGUCUAACCCAUAACU	CUUGAUGGGGUAGAGCUGGCUCAC	Translation
ath-miR405d	ZjuLEA-22	5.0	-1.0	AUGAGUUGGGUCUAACCCAUAACU	CUUGAUGGGGUAGAGCUGGCUCAC	Translation
ath-miR8181	ZjuLEA-22	5.0	-1.0	UGGGGGUGGGGGGGUGACAG	CCAUUACUCCUCCACCACCA	Cleavage
ath-miR167c-3p	ZjuLEA-23	5.0	-1.0	UAGGUCAUGCUGGUAGUUUCACC	CUCGAAGCUACCGCCAUGACCGC	Translation
ath-miR171a-3p	ZjuLEA-23	5.0	-1.0	UGAUUGAGCCGCGCCAAUAUC	GUGGCCGCCGCGGCUCAAUCA	Cleavage
ath-miR172d-5p	ZjuLEA-25	5.0	-1.0	GCAACAUCUUCAAGAUUCAGA	UCAAAAUCUUGAAGGUGUUCA	Cleavage
ath-miR842	ZjuLEA-26	5.0	-1.0	UCAUGGUCAGAUCCGUCAUCC	UCAUGGUGGUUCUGAUCGUAA	Cleavage
ath-miR5022	ZjuLEA-27	5.0	-1.0	GUCAUGGGGUAUGAUCGAAUG	GCUUGGAUCAUAUUACAUGUC	Cleavage
ath-miR5998a	ZjuLEA-27	5.0	-1.0	ACAGUUUGUGUUUUGUUUUGU	AAAAAAAAAAAAAAAAACUGA	Translation
ath-miR5998b	ZjuLEA-27	5.0	-1.0	ACAGUUUGUGUUUUGUUUUGU	AAAAAAAAAAAAAAAAACUGA	Translation
ath-miR8181	ZjuLEA-27	5.0	-1.0	UGGGGGUGGGGGGGUGACAG	AUCUCACUCCCCCAUUUUAA	Cleavage
ath-miR837-5p	ZjuLEA-27	5.0	-1.0	AUCAGUUUCUUGUUCGUUUCA	AAAAAAAAAAAAAAAACUGAU	Cleavage
ath-miR156b-3p	ZjuLEA-28	5.0	-1.0	UGCUCACCUCUCUUUCUGUCAGU	UUUAACUGACAGAGAGGUAAUCA	Cleavage
ath-miR172d-5p	ZjuLEA-28	5.0	-1.0	GCAACAUCUUCAAGAUUCAGA	GUUUAAUUUUGAGAGUGUUGG	Cleavage
ath-miR173-5p	ZjuLEA-28	5.0	-1.0	UUCGCUUGCAGAGAGAAAUCAC	GGAAUUUUGCUUUGCAUGUGAU	Cleavage
ath-miR1886.1	ZjuLEA-28	5.0	-1.0	UGAGAGAAGUGAGAUGAAAUC	CCUUUCUCUUCUCUUCUCUCU	Translation

ath-miR398a-5p	ZjuLEA-28	5.0	-1.0	AAGGAGUGGCAUGUGAACACA	CCGGUUUGCCUGUUGCUCCUU	Cleavage
ath-miR399b	ZjuLEA-28	5.0	-1.0	UGCCAAAGGAGAGUUGCCCUG	ACAAGAAGCUCUUCUUUGGCU	Cleavage
ath-miR399c-3p	ZjuLEA-28	5.0	-1.0	UGCCAAAGGAGAGUUGCCCUG	ACAAGAAGCUCUUCUUUGGCU	Cleavage
ath-miR401	ZjuLEA-28	5.0	-1.0	CGAAACUGGUGUCGACCGACA	CUUUGGUUGGUACCGGUUUGC	Cleavage
ath-miR4221	ZjuLEA-28	5.0	-1.0	UUUUCCUCUGUUGAAUUCUUGC	GUUAAGAUUCCAAAGAGGAGAA	Translation
ath-miR854a	ZjuLEA-28	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	CUUCUCUUCUCUCUUCUCCUC	Cleavage
ath-miR854b	ZjuLEA-28	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	CUUCUCUUCUCUCUUCUCCUC	Cleavage
ath-miR854c	ZjuLEA-28	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	CUUCUCUUCUCUCUUCUCCUC	Cleavage
ath-miR854d	ZjuLEA-28	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	CUUCUCUUCUCUCUUCUCCUC	Cleavage
ath-miR854e	ZjuLEA-28	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	CUUCUCUUCUCUCUUCUCCUC	Cleavage
ath-miR397a	ZjuLEA-29	5.0	-1.0	UCAUUGAGUGCAGCGUUGAUG	CAGAGACGCUUCGCUUAAUGA	Translation
ath-miR5021	ZjuLEA-29	5.0	-1.0	UGAGAAGAAGAAGAAGAAAA	GUCUCUUCCUCCUCUUCUCC	Cleavage
ath-miR8121	ZjuLEA-29	5.0	-1.0	AAAGUAUAAUGGUUUAGUGGUUUG	UCGUAAAAUUAACCAUUUUAUUUU	Cleavage
ath-miR854a	ZjuLEA-29	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AUCCUCUUCUUUUUUUUUAUU	Cleavage
ath-miR854a	ZjuLEA-29	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AUCCUCGCCGUUGUCCUCGUC	Cleavage
ath-miR854b	ZjuLEA-29	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AUCCUCUUCUUUUUUUUUAUU	Cleavage
ath-miR854b	ZjuLEA-29	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AUCCUCGCCGUUGUCCUCGUC	Cleavage
ath-miR854c	ZjuLEA-29	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AUCCUCUUCUUUUUUUUUAUU	Cleavage
ath-miR854c	ZjuLEA-29	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AUCCUCGCCGUUGUCCUCGUC	Cleavage
ath-miR854d	ZjuLEA-29	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AUCCUCUUCUUUUUUUUUAUU	Cleavage
ath-miR854d	ZjuLEA-29	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AUCCUCGCCGUUGUCCUCGUC	Cleavage
ath-miR854e	ZjuLEA-29	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AUCCUCUUCUUUUUUUUUAUU	Cleavage
ath-miR854e	ZjuLEA-29	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AUCCUCGCCGUUGUCCUCGUC	Cleavage
ath-miR1886.1	ZjuLEA-30	5.0	-1.0	UGAGAGAAGUGAGAUGAAAUC	GUAUUGAUUUUAUUUUUUUUA	Cleavage
ath-miR5663-3p	ZjuLEA-30	5.0	-1.0	UGAGAAUGCAAAUCCUUAGCU	AUCUAUGGCUUUGUAUUAUUA	Cleavage
ath-miR854a	ZjuLEA-30	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	UUCCUCAUCAUUGUCGUCAUC	Cleavage
ath-miR854b	ZjuLEA-30	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	UUCCUCAUCAUUGUCGUCAUC	Cleavage
ath-miR854c	ZjuLEA-30	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	UUCCUCAUCAUUGUCGUCAUC	Cleavage
ath-miR854d	ZjuLEA-30	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	UUCCUCAUCAUUGUCGUCAUC	Cleavage
ath-miR854e	ZjuLEA-30	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	UUCCUCAUCAUUGUCGUCAUC	Cleavage
ath-miR774b-5p	ZjuLEA-31	5.0	-1.0	UGAGAUGAAGAUAUGGGUGAU	CUCACCCACAUUUGCAUUUCU	Cleavage
ath-miR837-3p	ZjuLEA-31	5.0	-1.0	AAACGAACAAAAAACUGAUGG	AAAUUAAUUCGUUGUUUGUUU	Translation
ath-miR858a	ZjuLEA-31	5.0	-1.0	UUUCGUUGUCUGUUCGACCUU	CAGCUCGUACGGACGACGCAG	Cleavage
ath-miR858b	ZjuLEA-31	5.0	-1.0	UUCGUUGUCUGUUCGACCUUG	ACAGCUCGUACGGACGACGCA	Cleavage
ath-miR447a-3p	ZjuLEA-32	5.0	-1.0	UUGGGGACGAGAUGUUUUGUUG	UAAUAAAACUUUUCGUCCUGGA	Cleavage
ath-miR447b	ZjuLEA-32	5.0	-1.0	UUGGGGACGAGAUGUUUUGUUG	UAAUAAAACUUUUCGUCCUGGA	Cleavage
ath-miR829-5p	ZjuLEA-33	5.0	-1.0	ACUUUGAAGCUUUGAUUUGAA	UUCAGAAUGAAGCUUUAAGUU	Cleavage
ath-miR846-3p	ZjuLEA-33	5.0	-1.0	UUGAAUUGAAGUGCUUGAAUU	UUGUAAAGCUUUUCAAUUCAU	Cleavage
ath-miR865-3p	ZjuLEA-33	5.0	-1.0	UUUUUCCUCAAAUUUAUCCAA	AUUCAUACUUUUGAGGAAGAA	Cleavage
ath-miR866-5p	ZjuLEA-33	5.0	-1.0	UCAAGGAACGGAUUUUGUUAA	GAUACAAUAUUUUUUUCUUGA	Cleavage

ath-miR156g	ZjuLEA-34	5.0	-1.0	CGACAGAAGAGAGUGAGCAC	AAUCUCAUUUUCUUCUGAUG	Cleavage
ath-miR829-5p	ZjuLEA-34	5.0	-1.0	ACUUUGAAGCUUUGAUUUGAA	UUCAGAAUGAAGCUUUAAGUU	Cleavage
ath-miR865-3p	ZjuLEA-34	5.0	-1.0	UUUUUCCUCAAAUUUAUCCAA	AUUCAUACUUUUGAGGAAGAA	Cleavage
ath-miR866-5p	ZjuLEA-34	5.0	-1.0	UCAAGGAACGGAUUUUGUUAA	GAUACAAUAUUUUUUUCUUGA	Cleavage
ath-miR156i	ZjuLEA-35	5.0	-1.0	UGACAGAAGAGAGAGAGCAG	UUCCUUUCUUUAUUUUGUCC	Cleavage
ath-miR156j	ZjuLEA-35	5.0	-1.0	UGACAGAAGAGAGAGAGCAC	UUCCUUUCUUUAUUUUGUCC	Cleavage
ath-miR5019	ZjuLEA-35	5.0	-1.0	UGUUGGGAAAGAAAAACUCUU	AUGAUUUAUUUAUUCUCAAUA	Translation
ath-miR855	ZjuLEA-35	5.0	-1.0	AGCAAAAGCUAAGGAAAAGGAA	UUGCUAUUUCCUCGCUUUUGUU	Translation
ath-miR396b-3p	ZjuLEA-36	5.0	-1.0	GCUCAAGAAAGCUGUGGGAAA	UCGAUCCCAGCUUUCUUCAGC	Cleavage
ath-miR5641	ZjuLEA-36	5.0	-1.0	UGGAAGAAGAUGAUAGAAUUA	AUUUUCUUUUCUCUUCUUUUA	Translation
ath-miR8166	ZjuLEA-36	5.0	-1.0	AGAGAGUGUAGAAAGUUUCUCA	GGAGCAGCCGUCUACGUUCUCU	Cleavage
ath-miR843	ZjuLEA-36	5.0	-1.0	UUUAGGUCGAGCUUCAUUGGA	AUCAAAGGGACUCCACCUAAA	Cleavage
ath-miR4245	ZjuLEA-37	5.0	-1.0	ACAAAGUUUUAUACUGACAAU	CCAGUGAGAAUGAAACUUUGG	Cleavage
ath-miR773b-3p	ZjuLEA-37	5.0	-1.0	UUUGAUUCCAGCUUUUGUCUC	AAGUUGAAAACUGGAAGCAAA	Cleavage
ath-miR420	ZjuLEA-39	5.0	-1.0	UAAACUAAUCACGGAAAUGCA	AAUAUUUUGGUGGUUAUUUUG	Cleavage
ath-miR5021	ZjuLEA-39	5.0	-1.0	UGAGAAGAAGAAGAAGAAAA	UUUUAUUUUUUGUUUUUUUA	Cleavage
ath-miR5648-5p	ZjuLEA-39	5.0	-1.0	UUUGGAAAUAUUUGGCUUGACU	GUUUCAGCCGAAUAUUUUCAUU	Cleavage
ath-miR869.1	ZjuLEA-39	5.0	-1.0	AUUGGUUCAAUUCUGGUGUUG	CGAGACC-GAAUUGGGUCAGU	Cleavage
ath-miR5021	ZjuLEA-40	5.0	-1.0	UGAGAAGAAGAAGAAGAAAA	CAUUUUCCUUUUUCUUUGCA	Cleavage
ath-miR829-3p.1	ZjuLEA-40	5.0	-1.0	AGCUCUGAUACCAAAUGAUGGAAU	AUGGCAU-GUUUGGGAUUGGAGCU	Translation
ath-miR833a-5p	ZjuLEA-40	5.0	-1.0	UGUUUGUUGUACUCGGUCUAGU	UUAUGAACGAGUAUAGCAAGUU	Cleavage
ath-miR834	ZjuLEA-40	5.0	-1.0	UGGUAGCAGUAGCGGUGGUAA	UUACCAGCGGCACUGCUGCUA	Translation
ath-miR835-3p	ZjuLEA-40	5.0	-1.0	UGGAGAAGAUACGCAAGAAAG	UUUUCUUUUUUAUUUUCUUCU	Cleavage
ath-miR778	ZjuLEA-41	5.0	-1.0	UGGCUUGGUUUAUGUACACCG	UCUCCUACAGGAACCAAGCCA	Cleavage
ath-miR835-5p	ZjuLEA-41	5.0	-1.0	UUCUUGCAUAUGUU--CUUUAUC	UGUAAAGUCGAUAUAUGAAAGAA	Cleavage
ath-miR778	ZjuLEA-42	5.0	-1.0	UGGCUUGGUUUAUGUACACCG	UCUCCUACAGGAACCAAGCCA	Cleavage
ath-miR835-5p	ZjuLEA-42	5.0	-1.0	UUCUUGCAUAUGUU--CUUUAUC	UGUAAAGUCGAUAUAUGAAAGAA	Cleavage
ath-miR854a	ZjuLEA-42	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	CUUCUUCUUCUUUUUCUUAUU	Cleavage
ath-miR854b	ZjuLEA-42	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	CUUCUUCUUCUUUUUCUUAUU	Cleavage
ath-miR854c	ZjuLEA-42	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	CUUCUUCUUCUUUUUCUUAUU	Cleavage
ath-miR854d	ZjuLEA-42	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	CUUCUUCUUCUUUUUCUUAUU	Cleavage
ath-miR854e	ZjuLEA-42	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	CUUCUUCUUCUUUUUCUUAUU	Cleavage
ath-miR778	ZjuLEA-43	5.0	-1.0	UGGCUUGGUUUAUGUACACCG	UCUCCUACAGGAACCAAGCCA	Cleavage
ath-miR835-5p	ZjuLEA-43	5.0	-1.0	UUCUUGCAUAUGUU--CUUUAUC	UGUAAAGUCGAUAUAUGAAAGAA	Cleavage
ath-miR778	ZjuLEA-44	5.0	-1.0	UGGCUUGGUUUAUGUACACCG	UCUCCUACAGGAACCAAGCCA	Cleavage
ath-miR835-5p	ZjuLEA-44	5.0	-1.0	UUCUUGCAUAUGUU--CUUUAUC	UGUAAAGUCGAUAUAUGAAAGAA	Cleavage
ath-miR397b	ZjuLEA-45	5.0	-1.0	UCAUUGAGUGCAUCGUUGAUG	CUUGAAUGGUGCACCCAAUCA	Cleavage
ath-miR779.2	ZjuLEA-45	5.0	-1.0	UGAUUGGAAAUUUCGUUGACU	AAUUAUCAAAAUUAUCAAUUA	Cleavage
ath-miR8181	ZjuLEA-45	5.0	-1.0	UGGGGGUGGGGGGGUGACAG	ACGUCACGUCCACACCCCUA	Cleavage
ath-miR414	ZjuLEA-46	5.0	-1.0	UCAUCUUCAUCAUCAUCGUCA	AGACGAUGGAGGUAGGGAUGA	Cleavage

ath-miR4221	ZjuLEA-46	5.0	-1.0	UUUUCCUCUGUUGAAUUCUUGC	CAGGGAGAACAACAAAGGAAGA	Cleavage
ath-miR414	ZjuLEA-47	5.0	-1.0	UCAUCUUCAUCAUCAUCGUCA	AGACGAUGGAGGUAGGGAUGA	Cleavage
ath-miR4221	ZjuLEA-47	5.0	-1.0	UUUUCCUCUGUUGAAUUCUUGC	CAGGGAGAACAACAAAGGAAGA	Cleavage
ath-miR414	ZjuLEA-48	5.0	-1.0	UCAUCUUCAUCAUCAUCGUCA	AGACGAUGGAGGUAGGGAUGA	Cleavage
ath-miR4221	ZjuLEA-48	5.0	-1.0	UUUUCCUCUGUUGAAUUCUUGC	CAGGGAGAACAACAAAGGAAGA	Cleavage
ath-miR408-5p	ZjuLEA-49	5.0	-1.0	ACAGGGAACAAGCAGAGCAUG	AGCCUUCUGCUUUUUCCCUGG	Cleavage
ath-miR4239	ZjuLEA-49	5.0	-1.0	UUUGUUAUUUUCGCAUGCUCC	AGAGCCACUGGGAAUAACGAA	Cleavage
ath-miR4239	ZjuLEA-49	5.0	-1.0	UUUGUUAUUUUCGCAUGCUCC	CAACCUUGUGAAGAAAACGAA	Cleavage
ath-miR5636	ZjuLEA-49	5.0	-1.0	CGUAGUUGCAGAGCUUGACGG	GCGUCAAUGGCUGCAGCUGCG	Cleavage
ath-miR5642a	ZjuLEA-49	5.0	-1.0	UCUCGCGCUUGUACGGCUUU	CAGGCGGUGUAGGUGCGACA	Cleavage
ath-miR5642b	ZjuLEA-49	5.0	-1.0	UCUCGCGCUUGUACGGCUUU	CAGGCGGUGUAGGUGCGACA	Cleavage
ath-miR823	ZjuLEA-49	5.0	-1.0	UGGGUGGUGAUCAUAUAAGAU	CACUAAUAUGAGUACUACUCC	Translation
ath-miR841a-3p	ZjuLEA-49	5.0	-1.0	AUUUCUAGUGGGUCGUAUUCA	GAGGUGAGAGCCACUGGGAAU	Cleavage
ath-miR395a	ZjuLEA-50	5.0	-1.0	CUGAAGUGUUUGGGGGAACUC	CCGUUCACCCAAACUCUCCAC	Cleavage
ath-miR395d	ZjuLEA-50	5.0	-1.0	CUGAAGUGUUUGGGGGAACUC	CCGUUCACCCAAACUCUCCAC	Cleavage
ath-miR395e	ZjuLEA-50	5.0	-1.0	CUGAAGUGUUUGGGGGAACUC	CCGUUCACCCAAACUCUCCAC	Cleavage
ath-miR4243	ZjuLEA-50	5.0	-1.0	UUGAAAUUGUAGAUUUCGUAC	AAACUCGAUCUGUAAUUUAAA	Cleavage
ath-miR5997	ZjuLEA-50	5.0	-1.0	UGAAACCAAGUAGCUAAAUAG	AGGUGUAGCUAAUUGGUAUUA	Translation
ath-miR776	ZjuLEA-50	5.0	-1.0	UCUAAGUCUUCUAUUGAUGUU	UUCAUCCGUGGAAGUCUUCGA	Cleavage
ath-miR777	ZjuLEA-50	5.0	-1.0	UACGCAUUGAGUUUCGUUGCUU	UGGCAGGUAAACUCGAUCUGUA	Cleavage
ath-miR163	ZjuLEA-51	5.0	-1.0	UUGAAGAGGACUUGGAACUUCGAU	AAUCAUCCUUGAAGUUCUCUUCAA	Cleavage
ath-miR4245	ZjuLEA-51	5.0	-1.0	ACAAAGUUUUAUACUGACAAU	UAUUUUUGUAUAAAAAUUUGA	Cleavage
ath-miR780.1	ZjuLEA-51	5.0	-1.0	UCUAGCAGCUGUUGAGCAGGU	UAUUGCUAAACAAUUUCUAGA	Cleavage
ath-miR156h	ZjuLEA-52	5.0	-1.0	UGACAGAAGAAAGAGAGCAC	UAGUUUUUUUUUUUUUGGCA	Cleavage
ath-miR5012	ZjuLEA-52	5.0	-1.0	UUUUACUGCUACUUGUGUUCC	GCAAUCUAAGUGGUAAUAAAG	Cleavage
ath-miR5021	ZjuLEA-52	5.0	-1.0	UGAGAAGAAGAAGAAGAAAA	UUUUAGUUUUUUUUUUUUUG	Cleavage
ath-miR414	ZjuLEA-53	5.0	-1.0	UCAUCUUCAUCAUCAUCGUCA	AGGGGAUGAUCAUGAAUAUGG	Translation
ath-miR415	ZjuLEA-53	5.0	-1.0	AACAGAGCAGAAACAGAACAU	AUGUUUUCCAUUUGCUCUGUU	Cleavage
ath-miR5663-3p	ZjuLEA-53	5.0	-1.0	UGAGAAUGCAAAUCCUUAGCU	CAAUAGGGACUUGAAUUUUCA	Cleavage
ath-miR870-3p	ZjuLEA-53	5.0	-1.0	UAAUUUGGUGUUUCUUCGAUC	UGUUGUCCAAAUACUGAAUUA	Cleavage
ath-miR1886.1	ZjuLEA-54	5.0	-1.0	UGAGAGAAGUGAGAUGAAAUC	UUUUUCUUUUUCUUUUUUUCA	Translation
ath-miR826b	ZjuLEA-54	5.0	-1.0	UGGUUUUGGACACGUGAAAAU	AGAAUCCCGUAUUCAAAACCA	Translation
ath-miR837-3p	ZjuLEA-54	5.0	-1.0	AAACGAACAAA-AAACUGAUGG	CUAAUAGUUUGUUUGUUUGUUU	Translation
ath-miR858b	ZjuLEA-56	5.0	-1.0	UUCGUUGUCUGUUCGACCUUG	UAAAGGAGGACAGACAAGGAA	Cleavage
ath-miR156h	ZjuLEA-58	5.0	-1.0	UGACAGAAGAAAGAGAGCAC	UUGUUUUUUUUUUUUUUUUCU	Cleavage
ath-miR5017-3p	ZjuLEA-58	5.0	-1.0	UUAUACCAAAUUAAUAGCAAA	GUUGUUAUUA-UUUGGUAGAA	Translation
ath-miR5021	ZjuLEA-58	5.0	-1.0	UGAGAAGAAGAAGAAGAAAA	AUAUCUUCUUCUUGUUAUUG	Cleavage
ath-miR5024-5p	ZjuLEA-58	5.0	-1.0	AUGACAAGGCCAAGAUAUAACA	GUACAUAUCUUCUUCUUGUUAU	Translation
ath-miR837-3p	ZjuLEA-58	5.0	-1.0	AAACGAACAAAAAACUGAUGG	AGGUUUGGUUUUUGUUUUUUU	Cleavage
ath-miR417	ZjuLEA-59	5.0	-1.0	GAAGGUAGUGAAUUUGUUCGA	CAUAUCACAUUCACUAUCUAC	Cleavage

ath-miR5657	ZjuLEA-59	5.0	-1.0	UGGACAAGGUUAGAUUUGGUG	AGCAAGAUUUGGCUUUGUUCC	Cleavage
ath-miR5998a	ZjuLEA-59	5.0	-1.0	ACAGUUUGUGUUUUGUUUUGU	CAGAAAAGAAAUACAAACUUC	Cleavage
ath-miR5998a	ZjuLEA-59	5.0	-1.0	ACAGUUUGUGUUUUGUUUUGU	CAAGAGCAAGAC-CAAAUUGU	Cleavage
ath-miR5998b	ZjuLEA-59	5.0	-1.0	ACAGUUUGUGUUUUGUUUUGU	CAGAAAAGAAAUACAAACUUC	Cleavage
ath-miR5998b	ZjuLEA-59	5.0	-1.0	ACAGUUUGUGUUUUGUUUUGU	CAAGAGCAAGAC-CAAAUUGU	Cleavage
ath-miR8171	ZjuLEA-59	5.0	-1.0	AUAGGUGGGCCAGUGGUAGGA	GACUGCUACUAGUCCACUCAU	Translation
ath-miR156a-3p	ZjuLEA-60	5.0	-1.0	GCUCACUGCUCUUUCUGUCAGA	UGAGAGAGAGAGAGGGGGGAGC	Cleavage
ath-miR156d-3p	ZjuLEA-60	5.0	-1.0	GCUCACUCUCUUUUUGUCAUAAC	UAGAUGAGAGAGAGAGAGGGGGG	Cleavage
ath-miR401	ZjuLEA-60	5.0	-1.0	CGAAACUGGUGUCGACCGACA	UUUCUGAUGAUACCGGUAUCG	Cleavage
ath-miR5654-3p	ZjuLEA-60	5.0	-1.0	UGGAAGAUGCUUUGGGAUUUAUU	CGGCAAUUUCAGAUCCUCUUCCG	Translation
ath-miR157a-3p	ZjuLEA-62	5.0	-1.0	GCUCUCUAGCCUUCUGUCAUC	CAGCCGAGAAGGCUAGAGAGA	Cleavage
ath-miR157b-3p	ZjuLEA-62	5.0	-1.0	GCUCUCUAGCCUUCUGUCAUC	CAGCCGAGAAGGCUAGAGAGA	Cleavage
ath-miR171b-3p	ZjuLEA-62	5.0	-1.0	UUGAGCCGUGCCAAUAUCACG	UCUGCUACUGGUGCUGCUCGA	Cleavage
ath-miR171c-3p	ZjuLEA-62	5.0	-1.0	UUGAGCCGUGCCAAUAUCACG	UCUGCUACUGGUGCUGCUCGA	Cleavage
ath-miR859	ZjuLEA-62	5.0	-1.0	UCUCUCUGUUGUGAAGUCAAA	AAGGAUUAUACAACGGAGAAA	Cleavage
ath-miR868-5p	ZjuLEA-62	5.0	-1.0	UCAUGUCGUAAUAGUAGUCAC	AUGGCUUCUAUUUCGUCAUGG	Cleavage
ath-miR8181	ZjuLEA-63	5.0	-1.0	UGGGGGUGGGGGGGUGACAG	CUGCCACCCUUGCACCUCCU	Cleavage
ath-miR156h	ZjuLEA-65	5.0	-1.0	UGACAGAAGAAAGAGAGCAC	UUUUUUUUUUUUUUUUUUCA	Cleavage
ath-miR397a	ZjuLEA-65	5.0	-1.0	UCAUUGAGUGCAGCGUUGAUG	UCUUAGCGUUGCAUUUGAAGG	Cleavage
ath-miR397a	ZjuLEA-65	5.0	-1.0	UCAUUGAGUGCAGCGUUGAUG	UUACAACCUUGCUCUCAAUGC	Cleavage
ath-miR5014a-5p	ZjuLEA-65	5.0	-1.0	ACACUUAGUUUUGUACAACAU	ACCUUCCAGAAGACUAAGUGU	Cleavage
ath-miR5997	ZjuLEA-65	5.0	-1.0	UGAAACCAAGUAGCUAAAUAG	ACAUUUAUUUAUUUGUUUUUU	Cleavage
ath-miR857	ZjuLEA-65	5.0	-1.0	UUUUGUAUGUUGAAGGUGUAU	UAACGACUUUAACGAGCAGAA	Cleavage
ath-miR5662	ZjuLEA-66	5.0	-1.0	AGAGGUGACCAUUGGAGAUG	CAUCUCCGGUCGUUACCAUU	Translation
ath-miR5015	ZjuLEA-67	5.0	-1.0	UUGGUGUUAUGUGUAGUCUUC	CAAGGUUAAAUGUGACGUCAA	Cleavage
ath-miR1886.1	ZjuLEA-68	5.0	-1.0	UGAGAGAAGUGAGAUGAAAU	AGCUCAAAUCACUUUUCUCA	Cleavage
ath-miR5014a-3p	ZjuLEA-68	5.0	-1.0	UUGUACAAAUUUAAGUGUACG	CUUGCACAUAAAUUUUUCUAA	Cleavage
ath-miR862-3p	ZjuLEA-68	5.0	-1.0	AUAUGCUGGAUCUACUUGAAG	GGCCAAAUAGACCCAGCUUAU	Translation
ath-miR1886.1	ZjuLEA-69	5.0	-1.0	UGAGAGAAGUGAGAUGAAAUC	AAGCUCAAAUCACUUUUCUCA	Cleavage
ath-miR5014a-3p	ZjuLEA-69	5.0	-1.0	UUGUACAAAUUUAAGUGUACG	CUUGCACAUAAAUUUUUCUAA	Cleavage
ath-miR862-3p	ZjuLEA-69	5.0	-1.0	AUAUGCUGGAUCUACUUGAAG	GGCCAAAUAGACCCAGCUUAU	Translation
ath-miR4221	ZjuLEA-70	5.0	-1.0	UUUUCCUCUGUUGAAUUCUUGC	AAGAGUAUUGAAAAGAGGGGAA	Translation
ath-miR5020a	ZjuLEA-70	5.0	-1.0	UGGAAGAAGGUGAGACUUGCA	GUUAGGUUUCGUCGUUUUUCA	Cleavage
ath-miR5998a	ZjuLEA-71	5.0	-1.0	ACAGUUUGUGUUUUGUUUUGU	GAGAAACUAAAGGCAAGCUGC	Translation
ath-miR5998b	ZjuLEA-71	5.0	-1.0	ACAGUUUGUGUUUUGUUUUGU	GAGAAACUAAAGGCAAGCUGC	Translation
ath-miR825	ZjuLEA-71	5.0	-1.0	UUCUCAAGAAGGUGCAUGAAC	AGUUUUCUUUCUUCUUGAGAA	Cleavage
ath-miR1886.1	ZjuLEA-72	5.0	-1.0	UGAGAGAAGUGAGAUGAAAUC	CCUUUCUUUUCUUUUCUCUUC	Translation
ath-miR5020c	ZjuLEA-72	5.0	-1.0	UGGCAUGGAAGAAGGUGAGAC	CCCUUAACUCUUUCCUUGCCA	Cleavage
ath-miR420	ZjuLEA-73	5.0	-1.0	UAAACUAAUCACGGAAAUGCA	GAAAUUUUUGUGAUGAGUUCA	Cleavage
ath-miR5648-3p	ZjuLEA-73	5.0	-1.0	AUCUGAAGAAAAUAGCGGCAU	UCCUCCUUAUUUUCUUUGGAA	Cleavage

ath-miR5653	ZjuLEA-73	5.0	-1.0	UGGGUUGAGUUGAGUUGAGUUGGC	ACAGGCUCAUAUCAACUCAAGCUC	Cleavage
ath-miR773b-3p	ZjuLEA-73	5.0	-1.0	UUUGAUUCCAGCUUU-UGUCUC	GAGAAACAAGGUUGGAAUCAAU	Cleavage
ath-miR868-3p	ZjuLEA-73	5.0	-1.0	CUUCUUAAGUGCUGAUAAUGC	GCAACACCAGUACCUAAGAAG	Cleavage
ath-miR156d-3p	ZjuLEA-74	5.0	-1.0	GCUCACUCUCUUUUUGUCAUAAC	CAAAGGAAAAAAAAAGAGGGAGC	Translation
ath-miR854a	ZjuLEA-74	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR854b	ZjuLEA-74	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR854c	ZjuLEA-74	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR854d	ZjuLEA-74	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR854e	ZjuLEA-74	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR854a	ZjuLEA-75	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR854b	ZjuLEA-75	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR854c	ZjuLEA-75	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR854d	ZjuLEA-75	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR854e	ZjuLEA-75	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR3932a	ZjuLEA-76	5.0	-1.0	AACUUUGUGAUGACAACGAAG	GGUCAUUGUUAUCACAGCUUU	Cleavage
ath-miR3932b-3p	ZjuLEA-76	5.0	-1.0	AACUUUGUGAUGACAACGAAG	GGUCAUUGUUAUCACAGCUUU	Cleavage
ath-miR417	ZjuLEA-76	5.0	-1.0	GAAGGUAGUGAAUU--UGUUCGA	CGGAACACCAGUUCAUCACCUUC	Cleavage
ath-miR8165	ZjuLEA-76	5.0	-1.0	AAUGGAGGCAAGUGUGAAGGA	AACUCCACGGUUGCCUUCAGU	Cleavage
ath-miR869.2	ZjuLEA-76	5.0	-1.0	UCUGGUGUUGAGAUAGUUGAC	GACAGCGAGUUCAGCACCGGG	Cleavage
ath-miR156d-3p	ZjuLEA-77	5.0	-1.0	GCUCACUCUCUUUUUGUCAUAAC	CAAAGGAAAAAAAAAGAGGGAGC	Translation
ath-miR854a	ZjuLEA-77	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR854b	ZjuLEA-77	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR854c	ZjuLEA-77	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR854d	ZjuLEA-77	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR854e	ZjuLEA-77	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR156d-3p	ZjuLEA-78	5.0	-1.0	GCUCACUCUCUUUUUGUCAUAAC	AAAAAAAGAAGAAGAGAGGGAGC	Cleavage
ath-miR854a	ZjuLEA-78	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR854b	ZjuLEA-78	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR854c	ZjuLEA-78	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR854d	ZjuLEA-78	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR854e	ZjuLEA-78	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR156d-3p	ZjuLEA-79	5.0	-1.0	GCUCACUCUCUUUUUGUCAUAAC	AAAAAAAGAAGAAGAGAGGGAGC	Cleavage
ath-miR854a	ZjuLEA-79	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR854b	ZjuLEA-79	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR854c	ZjuLEA-79	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR854d	ZjuLEA-79	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR854e	ZjuLEA-79	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR156d-3p	ZjuLEA-80	5.0	-1.0	GCUCACUCUCUUUUUGUCAUAAC	CAAAGGAAAAAAAAAGAGGGAGC	Translation
ath-miR854a	ZjuLEA-80	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR854b	ZjuLEA-80	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage

ath-miR854c	ZjuLEA-80	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR854d	ZjuLEA-80	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR854e	ZjuLEA-80	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR156d-3p	ZjuLEA-81	5.0	-1.0	GCUCACUCUCUUUUUGUCAUAAC	CAAAGGAAAAAAAAAGAGGGAGC	Translation
ath-miR854a	ZjuLEA-81	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR854b	ZjuLEA-81	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR854c	ZjuLEA-81	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR854d	ZjuLEA-81	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR854e	ZjuLEA-81	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR156d-3p	ZjuLEA-82	5.0	-1.0	GCUCACUCUCUUUUUGUCAUAAC	CAAAGGAAAAAAAAAGAGGGAGC	Translation
ath-miR854a	ZjuLEA-82	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR854b	ZjuLEA-82	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR854c	ZjuLEA-82	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR854d	ZjuLEA-82	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR854e	ZjuLEA-82	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR156d-3p	ZjuLEA-83	5.0	-1.0	GCUCACUCUCUUUUUGUCAUAAC	CAAAGGAAAAAAAAAGAGGGAGC	Translation
ath-miR854a	ZjuLEA-83	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR854b	ZjuLEA-83	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR854c	ZjuLEA-83	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR854d	ZjuLEA-83	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR854e	ZjuLEA-83	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR156d-3p	ZjuLEA-84	5.0	-1.0	GCUCACUCUCUUUUUGUCAUAAC	AAAAAAAGAAGAAGAGAGGGAGC	Cleavage
ath-miR854a	ZjuLEA-84	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR854b	ZjuLEA-84	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR854c	ZjuLEA-84	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR854d	ZjuLEA-84	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR854e	ZjuLEA-84	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR156d-3p	ZjuLEA-85	5.0	-1.0	GCUCACUCUCUUUUUGUCAUAAC	CAAAGGAAAAAAAAAGAGGGAGC	Translation
ath-miR854a	ZjuLEA-85	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR854b	ZjuLEA-85	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR854c	ZjuLEA-85	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR854d	ZjuLEA-85	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR854e	ZjuLEA-85	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR3932a	ZjuLEA-86	5.0	-1.0	AACUUUGUGAUGACAACGAAG	GGUCAUUGUUAUCACAGCUUU	Cleavage
ath-miR3932b-3p	ZjuLEA-86	5.0	-1.0	AACUUUGUGAUGACAACGAAG	GGUCAUUGUUAUCACAGCUUU	Cleavage
ath-miR399c-5p	ZjuLEA-86	5.0	-1.0	GGGCAUCUUUCUAUUGGCAGG	AACGGCAAUGGGAAGAUGACU	Cleavage
ath-miR417	ZjuLEA-86	5.0	-1.0	GAAGGUAGUGAAUU--UGUUCGA	CGGAACACCAGUUCAUCACCUUC	Cleavage
ath-miR8165	ZjuLEA-86	5.0	-1.0	AAUGGAGGCAAGUGUGAAGGA	AACUCCACGGUUGCCUUCAGU	Cleavage
ath-miR156d-3p	ZjuLEA-87	5.0	-1.0	GCUCACUCUCUUUUUGUCAUAAC	CAAAGGAAAAAAAAAGAGGGAGC	Translation
ath-miR854a	ZjuLEA-87	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage

ath-miR854b	ZjuLEA-87	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR854c	ZjuLEA-87	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR854d	ZjuLEA-87	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR854e	ZjuLEA-87	5.0	-1.0	GAUGAGGAUAGGGAGGAGGAG	AAGCUUCUCUCUGCUCUCGUC	Cleavage
ath-miR156a-5p	ZjuLEA-88	5.0	-1.0	UGACAGAAGAGAGUGAGCAC	AUACUUAUUGUCUUUUGUCC	Translation
ath-miR156b-5p	ZjuLEA-88	5.0	-1.0	UGACAGAAGAGAGUGAGCAC	AUACUUAUUGUCUUUUGUCC	Translation
ath-miR156c-5p	ZjuLEA-88	5.0	-1.0	UGACAGAAGAGAGUGAGCAC	AUACUUAUUGUCUUUUGUCC	Translation
ath-miR156d-5p	ZjuLEA-88	5.0	-1.0	UGACAGAAGAGAGUGAGCAC	AUACUUAUUGUCUUUUGUCC	Translation
ath-miR156e	ZjuLEA-88	5.0	-1.0	UGACAGAAGAGAGUGAGCAC	AUACUUAUUGUCUUUUGUCC	Translation
ath-miR156f-5p	ZjuLEA-88	5.0	-1.0	UGACAGAAGAGAGUGAGCAC	AUACUUAUUGUCUUUUGUCC	Translation
ath-miR156g	ZjuLEA-88	5.0	-1.0	CGACAGAAGAGAGUGAGCAC	AUACUUAUUGUCUUUUGUCC	Translation
ath-miR156g	ZjuLEA-88	5.0	-1.0	CGACAGAAGAGAGUGAGCAC	UUCUUCUUCUUCUUCUGUCG	Cleavage
ath-miR157d	ZjuLEA-88	5.0	-1.0	UGACAGAAGAUAGAGAGCAC	AUACUUAUUGUCUUUUGUCC	Cleavage
ath-miR403-5p	ZjuLEA-88	5.0	-1.0	UGUUUUGUGCUUGAAUCUAAUU	GAAAAGAUUAAAACACAGAGCA	Translation
ath-miR5645a	ZjuLEA-88	5.0	-1.0	AUUUGAGUCAUGUCGUUAAG	GCUAACGAUAUGGUUCAUAA	Cleavage
ath-miR5645b	ZjuLEA-88	5.0	-1.0	AUUUGAGUCAUGUCGUUAAG	GCUAACGAUAUGGUUCAUAA	Cleavage
ath-miR5645d	ZjuLEA-88	5.0	-1.0	AUUUGAGUCAUGUCGUUAAG	GCUAACGAUAUGGUUCAUAA	Cleavage
ath-miR5645e	ZjuLEA-88	5.0	-1.0	AUUUGAGUCAUGUCGUUAAG	GCUAACGAUAUGGUUCAUAA	Cleavage
ath-miR5645f	ZjuLEA-88	5.0	-1.0	AUUUGAGUCAUGUCGUUAAG	GCUAACGAUAUGGUUCAUAA	Cleavage
ath-miR870-3p	ZjuLEA-88	5.0	-1.0	UAAUUUGGUGUUUCUUCGAUC	AUUUUAUGAAAAGCCAAGUUA	Translation
ath-miR3932a	ZjuLEA-89	5.0	-1.0	AACUUUGUGAUGACAACGAAG	GAUCAUUGUUAUCGCAAUUUU	Cleavage
ath-miR3932b-3p	ZjuLEA-89	5.0	-1.0	AACUUUGUGAUGACAACGAAG	GAUCAUUGUUAUCGCAAUUUU	Cleavage
ath-miR3932a	ZjuLEA-90	5.0	-1.0	AACUUUGUGAUGACAACGAAG	GAUCAUUGUUAUCGCAAUUUU	Cleavage
ath-miR3932b-3p	ZjuLEA-90	5.0	-1.0	AACUUUGUGAUGACAACGAAG	GAUCAUUGUUAUCGCAAUUUU	Cleavage
ath-miR158a-5p	ZjuLEA-91	5.0	-1.0	CUUUGUCUACAAUUUUGGAAA	AAGCCAAAGUUGAAGAAAAGG	Cleavage
ath-miR5631	ZjuLEA-91	5.0	-1.0	UGGCAGGAAAGACAUAAUUUU	GUAGUUUUGUUCUUCUUGCCU	Translation
ath-miR834	ZjuLEA-91	5.0	-1.0	UGGUAGCAGUAGCGGUGGUAA	GUACCAUGGCCAGUGCUGCCA	Translation
ath-miR837-5p	ZjuLEA-91	5.0	-1.0	AUCAGUUUCUUGUUCGUUUCA	AAAAAAGCAAAAGAAGCUGAG	Cleavage
ath-miR857	ZjuLEA-91	5.0	-1.0	UUUUGUAUGUUGAAGGUGUAU	AUACAGUUUUGAUAUAUAUAA	Cleavage
ath-miR5662	ZjuLEA-93	5.0	-1.0	AGAGGUGACCAUUGGAGAUG	CAUCUCCGGUCGUUACCAUU	Translation

Supplementary Table S3. Calculation of divergence time rates and Ka/Ks ratios of orthologous *ZjuLEA* gene pairs between jujube and peach, banana, orange, Arabidopsis.

Ziziphus jujuba – Prunus persica

ID	Chr.	Gene IDs	Chr.	Ks	Ka	Ka/Ks	Mya
ZjuLEA-01	1	Prupe.4G024900.1	4	1,1502	0,3387	0,294470527	8,847692308
ZjuLEA-01	1	Prupe.3G218800.1	3	2,5452	0,4593	0,180457331	19,57846154
ZjuLEA-02	1	Prupe.4G026800.1	4	0,7995	0,1746	0,218386492	6,15
ZjuLEA-05	1	Prupe.4G188100.1	4	1,9660	0,2658	0,135198372	15,12307692
ZjuLEA-05	1	Prupe.4G188500.1	4	1,2114	0,2159	0,178223543	9,318461538
ZjuLEA-05	1	Prupe.6G099800.1	6	37,474	0,4794	0,01279287	288,2615385
ZjuLEA-05	1	Prupe.6G099900.1	6	52,8201	0,5049	0,009558861	406,3084615
ZjuLEA-05	1	Prupe.6G100000.1	6	30,0554	0,5422	0,018040019	231,1953846
ZjuLEA-05	1	Prupe.8G132700.1	8	33,2201	0,6496	0,019554426	255,5392308
ZjuLEA-05	1	Prupe.6G125100.1	6	51,5830	0,6513	0,012626253	396,7923077
ZjuLEA-05	1	Prupe.6G125200.1	6	29,6234	0,6546	0,022097396	227,8723077
ZjuLEA-05	1	Prupe.6G125400.1	6	52,0073	0,6583	0,012657838	400,0561538
ZjuLEA-05	1	Prupe.6G124900.1	6	53,591	0,6474	0,012080387	412,2384615
ZjuLEA-06	1	Prupe.3G032500.1	3	0,9706	0,3229	0,332680816	7,466153846
ZjuLEA-07	1	Prupe.3G032500.1	3	1,0005	0,3299	0,329735132	7,696153846
ZjuLEA-08	1	Prupe.3G068000.1	3	1,1825	0,1425	0,1205074	9,096153846
ZjuLEA-08	1	Prupe.7G232800.1	7	2,0427	0,1613	0,078964116	15,71307692
ZjuLEA-08	1	Prupe.1G433700.1	1	51,3224	0,4690	0,00913831	394,7876923
ZjuLEA-08	1	Prupe.7G132000.1	7	3,0526	0,5198	0,170281072	23,48153846
ZjuLEA-09	1	Prupe.3G070600.1	3	1,1256	0,3061	0,271943852	8,658461538
ZjuLEA-09	1	Prupe.7G229800.1	7	6,1849	0,4044	0,065385051	47,57615385
ZjuLEA-10	1	Prupe.7G271000.1	7	1,9692	0,1165	0,059161081	15,14769231
ZjuLEA-11	1	Prupe.7G271000.1	7	1,9692	0,1165	0,059161081	15,14769231
ZjuLEA-12	1	Prupe.7G271000.1	7	1,9692	0,1165	0,059161081	15,14769231
ZjuLEA-13	1	Prupe.7G271000.1	7	1,9692	0,1165	0,059161081	15,14769231
ZjuLEA-15	2	Prupe.7G097100.1	7	73,1645	0,4295	0,005870333	562,8038462
ZjuLEA-15	2	Prupe.6G141400.1	6	36,6064	0,4390	0,011992438	281,5876923
ZjuLEA-16	2	Prupe.6G155500.1	6	2,2058	0,2692	0,12204189	16,96769231
ZjuLEA-17	2	Prupe.6G155500.1	6	2,2058	0,2692	0,12204189	16,96769231
ZjuLEA-20	2	Prupe.6G114100.1	6	1,0711	0,3650	0,34077117	8,239230769
ZjuLEA-21	2	Prupe.6G099800.1	6	0,9899	0,1572	0,15880392	7,614615385
ZjuLEA-21	2	Prupe.6G099900.1	6	1,1249	0,1709	0,151924616	8,653076923

ZjuLEA-21	2	Prupe.6G100000.1	6	1,0066	0,2184	0,216968011	7,743076923
ZjuLEA-21	2	Prupe.4G188100.1	4	47,6558	0,5183	0,010875906	366,5830769
ZjuLEA-21	2	Prupe.8G132700.1	8	4,9670	0,8030	0,161667002	38,20769231
ZjuLEA-21	2	Prupe.6G125200.1	6	3,9513	0,6021	0,152380229	30,39461538
ZjuLEA-21	2	Prupe.6G125400.1	6	4,1171	0,6070	0,147433873	31,67
ZjuLEA-21	2	Prupe.6G125100.1	6	3,9448	0,6187	0,156839383	30,34461538
ZjuLEA-21	2	Prupe.6G124900.1	6	4,6032	0,7759	0,168556656	35,40923077
ZjuLEA-21	2	Prupe.4G188500.1	4	5,0221	0,5592	0,111347843	38,63153846
ZjuLEA-22	2	Prupe.6G132700.1	6	1,0675	0,0983	0,092084309	8,211538462
ZjuLEA-22	2	Prupe.6G132600.1	6	0,9982	0,1593	0,159587257	7,678461538
ZjuLEA-23	2	Prupe.6G337900.2	6	1,4330	0,1946	0,135799023	11,02307692
ZjuLEA-23	2	Prupe.6G337900.1	6	1,4330	0,1946	0,135799023	11,02307692
ZjuLEA-23	2	Prupe.1G014800.1	1	4,2446	0,3453	0,081350422	32,65076923
ZjuLEA-23	2	Prupe.8G238700.1	8	4,6795	0,4051	0,086569078	35,99615385
ZjuLEA-28	3	Prupe.2G319000.1	2	1,1101	0,1368	0,123232141	8,539230769
ZjuLEA-29	4	Prupe.1G564500.2	1	2,3629	0,2108	0,089212408	18,17615385
ZjuLEA-29	4	Prupe.1G564500.1	1	2,1983	0,2146	0,097620889	16,91
ZjuLEA-30	4	Prupe.8G267700.1	8	1,9813	0,2280	0,11507596	15,24076923
ZjuLEA-30	4	Prupe.5G245100.1	5	2,9113	0,4501	0,154604472	22,39461538
ZjuLEA-33	5	Prupe.5G245100.1	5	1,2546	0,1884	0,150167384	9,650769231
ZjuLEA-33	5	Prupe.8G267700.1	8	2,7167	0,3767	0,138660875	20,89769231
ZjuLEA-34	5	Prupe.5G245100.1	5	1,2921	0,1973	0,15269716	9,939230769
ZjuLEA-34	5	Prupe.8G267700.1	8	2,3240	0,3870	0,166523236	17,87692308
ZjuLEA-35	6	Prupe.1G433700.1	1	1,0787	0,1012	0,093816631	8,297692308
ZjuLEA-35	6	Prupe.7G132000.1	7	1,5646	0,2235	0,142848012	12,03538462
ZjuLEA-35	6	Prupe.8G173100.2	8	11,1645	0,4393	0,039347933	85,88076923
ZjuLEA-35	6	Prupe.7G232800.1	7	51,7706	0,4303	0,008311667	398,2353846
ZjuLEA-35	6	Prupe.8G173100.1	8	11,1788	0,4393	0,039297599	85,99076923
ZjuLEA-36	6	Prupe.1G411400.1	1	1,2440	0,1931	0,15522508	9,569230769
ZjuLEA-36	6	Prupe.3G049400.1	3	2,1369	0,4310	0,201694043	16,43769231
ZjuLEA-38	7	Prupe.1G014800.1	1	1,3057	0,1892	0,144903117	10,04384615
ZjuLEA-38	7	Prupe.8G238700.1	8	9,8861	0,3479	0,035190823	76,04692308
ZjuLEA-38	7	Prupe.6G337900.2	6	3,5743	0,3173	0,088772627	27,49461538
ZjuLEA-38	7	Prupe.6G337900.1	6	3,5966	0,3410	0,094811767	27,66615385
ZjuLEA-40	8	Prupe.2G178500.1	2	1,7442	0,2116	0,121316363	13,41692308
ZjuLEA-40	8	Prupe.5G109900.1	5	3,1281	0,3963	0,126690323	24,06230769
ZjuLEA-41	8	Prupe.2G198600.1	2	1,1364	0,2021	0,177842309	8,741538462

ZjuLEA-42	8	Prupe.2G198600.1	2	1,1364	0,2021	0,177842309	8,741538462
ZjuLEA-43	8	Prupe.2G198600.1	2	1,1766	0,1815	0,154258032	9,050769231
ZjuLEA-44	8	Prupe.2G198600.1	2	1,1766	0,1815	0,154258032	9,050769231
ZjuLEA-45	8	Prupe.7G132000.1	7	1,0707	0,1279	0,119454562	8,236153846
ZjuLEA-45	8	Prupe.1G433700.1	1	1,9274	0,2061	0,106931618	14,82615385
ZjuLEA-45	8	Prupe.3G068000.1	3	21,7749	0,5257	0,024142476	167,4992308
ZjuLEA-45	8	Prupe.8G173100.2	8	3,3434	0,4362	0,130465993	25,71846154
ZjuLEA-45	8	Prupe.8G173100.1	8	3,3434	0,4362	0,130465993	25,71846154
ZjuLEA-45	8	Prupe.7G132000.2	7	1,1850	0,1345	0,11350211	9,115384615
ZjuLEA-45	8	Prupe.7G232800.1	7	51,6645	0,4792	0,009275228	397,4192308
ZjuLEA-49	9	Prupe.8G238700.1	8	2,2082	0,2306	0,104428947	16,98615385
ZjuLEA-49	9	Prupe.1G014800.1	1	42,0122	0,2768	0,006588562	323,1707692
ZjuLEA-49	9	Prupe.6G337900.2	6	2,2986	0,3999	0,173975463	17,68153846
ZjuLEA-49	9	Prupe.6G337900.1	6	2,2441	0,4027	0,179448331	17,26230769
ZjuLEA-50	9	Prupe.8G270400.1	8	0,7539	0,0756	0,100278552	5,799230769
ZjuLEA-51	10	Prupe.1G242600.1	1	1,3355	0,3957	0,296293523	10,27307692
ZjuLEA-52	11	Prupe.5G121700.1	5	1,0158	0,1696	0,166962	7,813846154
ZjuLEA-53	11	Prupe.5G109900.1	5	2,3063	0,3012	0,130598795	17,74076923
ZjuLEA-53	11	Prupe.2G178500.1	2	53,6854	0,4111	0,007657575	412,9646154
ZjuLEA-54	11	Prupe.5G109800.1	5	1,5183	0,3202	0,210893763	11,67923077
ZjuLEA-57	11	Prupe.5G014700.1	5	1,5063	0,2253	0,149571798	11,58692308
ZjuLEA-58	11	Prupe.6G299500.1	6	18,8589	0,3382	0,017933177	145,0684615
ZjuLEA-59	11	Prupe.6G299100.1	6	1,6299	0,1908	0,117062396	12,53769231
ZjuLEA-60	12	Prupe.7G232800.1	7	1,3185	0,1132	0,085855138	10,14230769
ZjuLEA-60	12	Prupe.3G068000.1	3	1,733	0,2196	0,126716676	13,33076923
ZjuLEA-60	12	Prupe.1G433700.1	1	56,2377	0,4900	0,008713016	432,5976923
ZjuLEA-61	12	Prupe.7G229800.1	7	1,1620	0,1600	0,137693632	8,938461538
ZjuLEA-63	12	Prupe.7G111600.1	7	1,9749	0,3629	0,18375614	15,19153846
ZjuLEA-63	12	Prupe.7G111300.1	7	1,7586	0,3950	0,224610486	13,52769231
ZjuLEA-63	12	Prupe.7G111500.1	7	1,4938	0,3854	0,257999732	11,49076923
ZjuLEA-63	12	Prupe.7G112000.1	7	1,7836	0,3771	0,211426329	13,72
ZjuLEA-63	12	Prupe.7G111900.1	7	1,3303	0,4373	0,328722844	10,23307692
ZjuLEA-64	12	Prupe.7G097200.1	7	1,9794	0,2971	0,150095989	15,22615385
ZjuLEA-65	12	Prupe.7G097200.1	7	3,2306	0,3585	0,110970098	24,85076923
ZjuLEA-66	12	Prupe.7G097100.1	7	40,8204	0,1569	0,003843666	314,0030769
ZjuLEA-66	12	Prupe.6G141400.1	6	59,7211	0,4711	0,007888334	459,3930769
ZjuLEA-67	12	Prupe.7G097200.1	7	11,9984	0,2451	0,020427724	92,29538462

ZjuLEA-68	12	Prupe.7G097000.2	7	1,6993	0,3515	0,206849879	13,07153846
ZjuLEA-68	12	Prupe.7G097000.1	7	1,6993	0,3515	0,206849879	13,07153846
ZjuLEA-69	12	Prupe.7G097000.2	7	1,6993	0,3515	0,206849879	13,07153846
ZjuLEA-69	12	Prupe.7G097000.1	7	1,6993	0,3515	0,206849879	13,07153846
ZjuLEA-72	NW	Prupe.3G049400.1	3	1,6137	0,2223	0,137757948	12,41307692
ZjuLEA-73	NW	Prupe.6G029700.1	6	0,6353	0,1575	0,247914371	4,886923077
ZjuLEA-88	NW	Prupe.1G554000.1	1	2,1951	0,5063	0,230650084	16,88538462
ZjuLEA-93	NW	Prupe.7G097100.1	7	40,5207	0,1567	0,003867159	311,6976923
ZjuLEA-93	NW	Prupe.6G141400.1	6	59,7177	0,4711	0,007888783	459,3669231
Mean				11,04	0,33	0,124	84,89

Ziziphus jujuba – Musa accuminata

ID	Chr.	Gene IDs	Chr.	Ks	Ka	Ka/Ks	Mya
ZjuLEA-02	1	GSMUA_Achr6T29330_001	6	54,9718	0,4044	0,007356499	422,86
ZjuLEA-02	1	GSMUA_Achr9T11960_001	9	9,2994	0,4087	0,043949072	71,53384615
ZjuLEA-05	1	GSMUA_Achr9T12230_001	9	12,0977	0,3240	0,02678195	93,05923077
ZjuLEA-05	1	GSMUA_Achr1T17700_001	1	65,1613	0,3856	0,005917623	501,2407692
ZjuLEA-05	1	GSMUA_Achr11T06920_001	11	57,2259	0,4994	0,008726818	440,1992308
ZjuLEA-05	1	GSMUA_Achr11T01270_001	11	0,0976	9,661	98,98565574	0,750769231
ZjuLEA-08	1	GSMUA_Achr6T14060_001	6	2,5734	0,1864	0,072433357	19,79538462
ZjuLEA-08	1	GSMUA_Achr10T22080_001	10	47,3192	0,1971	0,004165328	363,9938462
ZjuLEA-08	1	GSMUA_Achr7T14390_001	7	2,7706	0,1930	0,069660001	21,31230769
ZjuLEA-08	1	GSMUA_Achr8T30310_001	8	34,9425	0,4427	0,012669385	268,7884615
ZjuLEA-08	1	GSMUA_Achr6T19670_001	6	4,6285	0,6785	0,146591768	35,60384615
ZjuLEA-08	1	GSMUA_Achr8T13200_001	8	28,259	0,5615	0,019869776	217,3769231
ZjuLEA-09	1	GSMUA_Achr8T15540_001	8	7,6231	0,4634	0,060788918	58,63923077
ZjuLEA-10	1	GSMUA_Achr10T04300_001	10	3,9818	0,1472	0,036968205	30,62923077
ZjuLEA-11	1	GSMUA_Achr10T04300_001	10	3,9814	0,1472	0,036971919	30,62615385
ZjuLEA-12	1	GSMUA_Achr10T04300_001	10	3,9821	0,1472	0,03696542	30,63153846
ZjuLEA-13	1	GSMUA_Achr10T04300_001	10	3,9815	0,1472	0,036970991	30,62692308
ZjuLEA-15	2	GSMUA_Achr7T03290_001	7	87,1577	0,4251	0,004877366	670,4438462
ZjuLEA-15	2	GSMUA_Achr8T34450_001	8	69,8797	0,4470	0,006396707	537,5361538
ZjuLEA-15	2	GSMUA_Achr9T08960_001	9	83,2025	0,4801	0,005770259	640,0192308
ZjuLEA-15	2	GSMUA_Achr10T04670_001	10	91,8446	0,4516	0,004917001	706,4969231
ZjuLEA-15	2	GSMUA_Achr6T19500_001	6	82,7191	0,4604	0,005565825	636,3007692
ZjuLEA-15	2	GSMUA_AchrUn_randomT27690_001	scaffold	82,7697	0,4725	0,005708611	636,69
ZjuLEA-16	2	GSMUA_Achr3T03620_001	3	5,2807	0,4819	0,091256841	40,62076923
ZjuLEA-17	2	GSMUA_Achr3T03620_001	3	5,2806	0,4819	0,091258569	40,62

ZjuLEA-21	2	GSMUA_Achr11T06920_001	11	54,2198	0,2884	0,00531909	417,0753846
ZjuLEA-21	2	GSMUA_Achr9T12230_001	9	16,3280	0,4880	0,02988731	125,6
ZjuLEA-21	2	GSMUA_Achr1T17700_001	1	29,8293	0,5388	0,018062777	229,4561538
ZjuLEA-21	2	GSMUA_Achr11T01270_001	11	50,1508	0,6090	0,012143376	385,7753846
ZjuLEA-28	3	GSMUA_Achr5T14440_001	5	3,8389	0,2742	0,071426711	29,53
ZjuLEA-28	3	GSMUA_Achr4T18020_001	4	2,3624	0,3067	0,129825601	18,17230769
ZjuLEA-30	4	GSMUA_Achr5T11970_001	5	8,0932	0,3613	0,044642416	62,25538462
ZjuLEA-30	4	GSMUA_Achr9T20600_001	9	7,0714	0,3930	0,055575982	54,39538462
ZjuLEA-30	4	GSMUA_Achr3T14210_001	3	43,3106	0,3783	0,008734582	333,1584615
ZjuLEA-30	4	GSMUA_Achr1T17720_001	1	12,6318	0,4031	0,031911525	97,16769231
ZjuLEA-33	5	GSMUA_Achr5T11970_001	5	9,3233	0,3225	0,034590756	71,71769231
ZjuLEA-33	5	GSMUA_Achr9T20600_001	9	8,2733	0,4069	0,049182309	63,64076923
ZjuLEA-33	5	GSMUA_Achr3T14210_001	3	57,5146	0,3712	0,006454013	442,42
ZjuLEA-34	5	GSMUA_Achr5T11970_001	5	9,0327	0,3257	0,036057879	69,48230769
ZjuLEA-34	5	GSMUA_Achr9T20600_001	9	6,8939	0,4144	0,060111113	53,03
ZjuLEA-34	5	GSMUA_Achr3T14210_001	3	57,0205	0,3761	0,006595873	438,6192308
ZjuLEA-35	6	GSMUA_Achr8T30310_001	8	5,8114	0,2043	0,03515504	44,70307692
ZjuLEA-35	6	GSMUA_Achr6T19670_001	6	9,4957	0,2426	0,025548406	73,04384615
ZjuLEA-35	6	GSMUA_Achr2T08190_001	2	13,3652	0,2472	0,018495795	102,8092308
ZjuLEA-35	6	GSMUA_Achr8T13200_001	8	9,1584	0,4124	0,0450297	70,44923077
ZjuLEA-35	6	GSMUA_Achr10T09590_001	10	7,9660	0,3517	0,044150138	61,27692308
ZjuLEA-35	6	GSMUA_Achr10T22080_001	10	51,7087	0,4520	0,008741276	397,7592308
ZjuLEA-35	6	GSMUA_Achr6T14060_001	6	50,5544	0,4483	0,008867675	388,88
ZjuLEA-35	6	GSMUA_Achr7T14390_001	7	51,0801	0,4560	0,008927156	392,9238462
ZjuLEA-38	7	GSMUA_Achr4T14830_001	4	11,5952	0,4389	0,03785187	89,19384615
ZjuLEA-38	7	GSMUA_Achr3T25520_001	3	4,2896	0,4076	0,095020515	32,99692308
ZjuLEA-38	7	GSMUA_Achr7T27190_001	7	40,7013	0,3908	0,009601659	313,0869231
ZjuLEA-38	7	GSMUA_Achr3T30940_001	3	10,4757	0,4100	0,039138196	80,58230769
ZjuLEA-41	8	GSMUA_AchrUn_randomT07400_001	scaffold	36,2127	0,2722	0,0075167	278,5592308
ZjuLEA-42	8	GSMUA_AchrUn_randomT07400_001	scaffold	35,3307	0,2722	0,007704348	271,7746154
ZjuLEA-43	8	GSMUA_AchrUn_randomT07400_001	scaffold	35,7558	0,2723	0,007615548	275,0446154
ZjuLEA-44	8	GSMUA_AchrUn_randomT07400_001	scaffold	37,5835	0,2723	0,007245201	289,1038462
ZjuLEA-45	8	GSMUA_Achr8T30310_001	8	35,0376	0,2390	0,006821243	269,52
ZjuLEA-45	8	GSMUA_Achr6T19670_001	6	4,8603	0,2698	0,055510977	37,38692308
ZjuLEA-45	8	GSMUA_Achr2T08190_001	2	4,0344	0,2518	0,062413246	31,03384615
ZjuLEA-45	8	GSMUA_Achr10T09590_001	10	5,1837	0,3357	0,064760692	39,87461538
ZjuLEA-45	8	GSMUA_Achr10T22080_001	10	10,7335	0,4917	0,045809848	82,56538462

ZjuLEA-45	8	GSMUA_Achr6T14060_001	6	50,4520	0,5002	0,009914374	388,0923077
ZjuLEA-45	8	GSMUA_Achr7T14390_001	7	50,0900	0,5058	0,010097824	385,3076923
ZjuLEA-45	8	GSMUA_Achr8T13200_001	8	12,0498	0,3982	0,033046192	92,69076923
ZjuLEA-45	8	GSMUA_Achr11T11990_001	11	5,4421	0,4218	0,077506845	41,86230769
ZjuLEA-49	9	GSMUA_Achr4T14830_001	4	22,7843	0,4533	0,019895279	175,2638462
ZjuLEA-49	9	GSMUA_Achr3T25520_001	3	41,1226	0,4392	0,010680259	316,3276923
ZjuLEA-49	9	GSMUA_Achr7T27190_001	7	42,2899	0,4541	0,010737788	325,3069231
ZjuLEA-50	9	GSMUA_Achr3T24270_001	3	1,9162	0,2029	0,105886651	14,74
ZjuLEA-50	9	GSMUA_Achr5T27110_001	5	2,3081	0,1976	0,085611542	17,75461538
ZjuLEA-50	9	GSMUA_Achr8T06470_001	8	2,4460	0,2043	0,083524121	18,81538462
ZjuLEA-52	11	GSMUA_Achr8T15980_001	8	66,4565	0,3379	0,005084529	511,2038462
ZjuLEA-59	11	GSMUA_Achr4T10340_001	4	57,8463	0,4660	0,008055831	444,9715385
ZjuLEA-60	12	GSMUA_Achr6T14060_001	6	2,8207	0,2299	0,081504591	21,69769231
ZjuLEA-60	12	GSMUA_Achr10T22080_001	10	9,2301	0,2545	0,027572832	71,00076923
ZjuLEA-60	12	GSMUA_Achr7T14390_001	7	3,6536	0,2499	0,068398292	28,10461538
ZjuLEA-60	12	GSMUA_Achr8T30310_001	8	12,5440	0,5209	0,041525829	96,49230769
ZjuLEA-66	12	GSMUA_Achr6T19500_001	6	91,2903	0,4482	0,004909613	702,2330769
ZjuLEA-66	12	GSMUA_Achr9T08960_001	9	94,643	0,3585	0,003787919	728,0230769
ZjuLEA-66	12	GSMUA_AchrUn_randomT27690_001	scaffold	76,9273	0,3644	0,00473694	591,7484615
ZjuLEA-66	12	GSMUA_Achr7T03290_001	7	83,4539	0,3731	0,004470732	641,9530769
ZjuLEA-66	12	GSMUA_Achr8T34450_001	8	75,7922	0,4577	0,00603888	583,0169231
ZjuLEA-66	12	GSMUA_Achr10T04670_001	10	105,4155	0,4081	0,003871347	810,8884615
ZjuLEA-67	12	GSMUA_Achr9T29680_001	9	9,9340	0,4174	0,042017314	76,41538462
ZjuLEA-73	NW	GSMUA_Achr9T27930_001	9	5,6464	0,3833	0,067883961	43,43384615
ZjuLEA-93	NW	GSMUA_Achr9T08960_001	9	89,3162	0,3588	0,004017188	687,0476923
ZjuLEA-93	NW	GSMUA_AchrUn_randomT27690_001	scaffold	78,4883	0,3648	0,004647826	603,7561538
ZjuLEA-93	NW	GSMUA_Achr7T03290_001	7	77,507	0,3729	0,004811178	596,2076923
ZjuLEA-93	NW	GSMUA_Achr8T34450_001	8	75,7868	0,4577	0,00603931	582,9753846
ZjuLEA-93	NW	GSMUA_Achr10T04670_001	10	105,4188	0,4078	0,00386838	810,9138462
ZjuLEA-93	NW	GSMUA_Achr6T19500_001	6	91,2570	0,4488	0,004917979	701,9769231
Mean				34,15	0,47	1,11	262,72

Ziziphus jujuba – Citrus sinensis

ID	Chr.	Gene IDs	Chr.	Ks	Ka	Ka/Ks	Mya
ZjuLEA-01	1	orange1.1g044545m	scaffold	1,6034	0,3814	0,237869527	12,33384615
ZjuLEA-02	1	orange1.1g042582m	scaffold	1,0722	0,3033	0,282876329	8,247692308
ZjuLEA-05	1	orange1.1g039782m	scaffold	1,8963	0,2049	0,108052523	14,58692308
ZjuLEA-05	1	orange1.1g042767m	scaffold	55,296	0,2496	0,004513889	425,3538462

ZjuLEA-05	1	orange1.1g040244m	scaffold	12,0606	0,5246	0,043497007	92,77384615
ZjuLEA-05	1	orange1.1g039053m	scaffold	50,9684	0,5143	0,010090566	392,0646154
ZjuLEA-08	1	orange1.1g022177m	scaffold	2,8697	0,1998	0,069624003	22,07461538
ZjuLEA-08	1	orange1.1g047795m	scaffold	50,1148	0,4939	0,009855372	385,4984615
ZjuLEA-08	1	orange1.1g020687m	scaffold	50,7671	0,4416	0,008698547	390,5161538
ZjuLEA-09	1	orange1.1g027729m	scaffold	10,0380	0,3829	0,038145049	77,21538462
ZjuLEA-09	1	orange1.1g028106m	scaffold	2,2757	0,3880	0,17049699	17,50538462
ZjuLEA-09	1	orange1.1g028822m	scaffold	14,6413	0,4267	0,029143587	112,6253846
ZjuLEA-10	1	orange1.1g018706m	scaffold	1,4349	0,0635	0,044253955	11,03769231
ZjuLEA-11	1	orange1.1g018706m	scaffold	1,4349	0,0635	0,044253955	11,03769231
ZjuLEA-12	1	orange1.1g018706m	scaffold	1,4349	0,0635	0,044253955	11,03769231
ZjuLEA-13	1	orange1.1g018706m	scaffold	1,4349	0,0635	0,044253955	11,03769231
ZjuLEA-15	2	orange1.1g028208m	scaffold	43,1877	0,2989	0,006920952	332,2130769
ZjuLEA-15	2	orange1.1g028399m	scaffold	28,9246	0,4045	0,013984636	222,4969231
ZjuLEA-16	2	orange1.1g025262m	scaffold	3,0625	0,3182	0,103902041	23,55769231
ZjuLEA-17	2	orange1.1g025262m	scaffold	3,0625	0,3182	0,103902041	23,55769231
ZjuLEA-20	2	orange1.1g028932m	scaffold	1,828	0,3424	0,187308534	14,06153846
ZjuLEA-21	2	orange1.1g039053m	scaffold	1,5038	0,1685	0,112049475	11,56769231
ZjuLEA-21	2	orange1.1g040244m	scaffold	1,5949	0,2060	0,129161703	12,26846154
ZjuLEA-21	2	orange1.1g039782m	scaffold	2,593	0,5731	0,221018126	19,94615385
ZjuLEA-21	2	orange1.1g042767m	scaffold	3,3209	0,4938	0,148694631	25,54538462
ZjuLEA-22	2	orange1.1g030102m	scaffold	1,2341	0,1403	0,113686087	9,493076923
ZjuLEA-23	2	orange1.1g046001m	scaffold	3,9468	0,2202	0,055792034	30,36
ZjuLEA-23	2	orange1.1g038380m	scaffold	9,9901	0,3540	0,035435081	76,84692308
ZjuLEA-23	2	orange1.1g035654m	scaffold	3,7042	0,4214	0,113762756	28,49384615
ZjuLEA-29	4	orange1.1g023930m	scaffold	3,5096	0,2525	0,071945521	26,99692308
ZjuLEA-30	4	orange1.1g045040m	scaffold	2,3066	0,2727	0,11822596	17,74307692
ZjuLEA-30	4	orange1.1g047356m	scaffold	1,9663	0,3766	0,191527234	15,12538462
ZjuLEA-33	5	orange1.1g047356m	scaffold	1,6312	0,2013	0,123406081	12,54769231
ZjuLEA-33	5	orange1.1g045040m	scaffold	4,1670	0,3726	0,089416847	32,05384615
ZjuLEA-34	5	orange1.1g047356m	scaffold	1,5558	0,2055	0,132086386	11,96769231
ZjuLEA-34	5	orange1.1g045040m	scaffold	3,7577	0,3869	0,102961918	28,90538462
ZjuLEA-35	6	orange1.1g020687m	scaffold	1,0492	0,1018	0,097026306	8,070769231
ZjuLEA-35	6	orange1.1g047795m	scaffold	1,2747	0,2443	0,191652938	9,805384615
ZjuLEA-35	6	orange1.1g021795m	scaffold	2,6532	0,4074	0,15355043	20,40923077
ZjuLEA-35	6	orange1.1g022177m	scaffold	55,977	0,4025	0,007190453	430,5923077
ZjuLEA-36	6	orange1.1g038352m	scaffold	1,4228	0,2706	0,190188361	10,94461538

ZjuLEA-38	7	orange1.1g038380m	scaffold	15,9296	0,1943	0,012197419	122,5353846
ZjuLEA-38	7	orange1.1g046001m	scaffold	11,3127	0,2805	0,024795142	87,02076923
ZjuLEA-38	7	orange1.1g035654m	scaffold	7,3915	0,3008	0,040695393	56,85769231
ZjuLEA-40	8	orange1.1g048098m	scaffold	5,3785	0,3939	0,073236032	41,37307692
ZjuLEA-41	8	orange1.1g038323m	scaffold	1,7873	0,2371	0,1326582	13,74846154
ZjuLEA-42	8	orange1.1g038323m	scaffold	1,7873	0,2371	0,1326582	13,74846154
ZjuLEA-43	8	orange1.1g038323m	scaffold	1,7873	0,2371	0,1326582	13,74846154
ZjuLEA-44	8	orange1.1g038323m	scaffold	1,7873	0,2371	0,1326582	13,74846154
ZjuLEA-45	8	orange1.1g047795m	scaffold	1,8001	0,1595	0,088606189	13,84692308
ZjuLEA-45	8	orange1.1g020687m	scaffold	2,6168	0,2058	0,078645674	20,12923077
ZjuLEA-45	8	orange1.1g021795m	scaffold	3,8795	0,4434	0,114293079	29,84230769
ZjuLEA-45	8	orange1.1g022177m	scaffold	11,0825	0,4449	0,040144372	85,25
ZjuLEA-49	9	orange1.1g038380m	scaffold	8,5836	0,3449	0,040181276	66,02769231
ZjuLEA-49	9	orange1.1g046001m	scaffold	6,6880	0,3890	0,058163876	51,44615385
ZjuLEA-49	9	orange1.1g027886m	scaffold	3,4697	0,2487	0,071677667	26,69
ZjuLEA-49	9	orange1.1g035654m	scaffold	13,1619	0,3918	0,029767739	101,2453846
ZjuLEA-50	9	orange1.1g028150m	scaffold	0,8510	0,0659	0,077438308	6,546153846
ZjuLEA-51	10	orange1.1g043069m	scaffold	1,6692	0,5074	0,303977954	12,84
ZjuLEA-52	11	orange1.1g048760m	scaffold	1,6320	0,2125	0,130208333	12,55384615
ZjuLEA-53	11	orange1.1g043236m	scaffold	6,0990	0,4289	0,070323004	46,91538462
ZjuLEA-57	11	orange1.1g029005m	scaffold	2,6048	0,3209	0,123195639	20,03692308
ZjuLEA-58	11	orange1.1g028071m	scaffold	8,5197	0,4693	0,055084099	65,53615385
ZjuLEA-59	11	orange1.1g028279m	scaffold	2,2076	0,3015	0,136573655	16,98153846
ZjuLEA-60	12	orange1.1g022177m	scaffold	1,8074	0,1474	0,081553613	13,90307692
ZjuLEA-60	12	orange1.1g047795m	scaffold	8,4307	0,5336	0,063292491	64,85153846
ZjuLEA-60	12	orange1.1g020687m	scaffold	12,0068	0,4487	0,03737049	92,36
ZjuLEA-61	12	orange1.1g028106m	scaffold	1,7938	0,2202	0,12275616	13,79846154
ZjuLEA-64	12	orange1.1g027210m	scaffold	1,9278	0,4072	0,211225231	14,82923077
ZjuLEA-65	12	orange1.1g027210m	scaffold	8,3177	0,4064	0,048859661	63,98230769
ZjuLEA-66	12	orange1.1g028399m	scaffold	64,2033	0,1853	0,002886144	493,8715385
ZjuLEA-66	12	orange1.1g028208m	scaffold	15,5101	0,3401	0,021927647	119,3084615
ZjuLEA-67	12	orange1.1g027210m	scaffold	16,6693	0,2859	0,01715129	128,2253846
ZjuLEA-68	12	orange1.1g026507m	scaffold	54,1430	0,4902	0,009053802	416,4846154
ZjuLEA-69	12	orange1.1g026507m	scaffold	54,1460	0,4902	0,0090533	416,5076923
ZjuLEA-72	NW	orange1.1g024226m	scaffold	1,5467	0,2656	0,171720437	11,89769231
ZjuLEA-73	NW	orange1.1g037451m	scaffold	0,7964	0,1988	0,249623305	6,126153846
ZjuLEA-88	NW	orange1.1g037813m	scaffold	49,0402	0,4391	0,008953879	377,2323077

ZjuLEA-93	NW	orange1.1g028399m	scaffold	64,2066	0,1856	0,002890669	493,8969231
ZjuLEA-93	NW	orange1.1g028208m	scaffold	15,4600	0,3401	0,021998706	118,9230769
Mean				11,76	0,31	0,09	90,44

Ziziphus jujuba – Arabidopsis thaliana

ID	Chr.	Gene IDs	Chr.	Ks	Ka	Ka/Ks	Mya
ZjuLEA-02	1	AT4G05220.1	4	7,8297	0,2924	0,037344981	60,22846154
ZjuLEA-02	1	AT1G61760.1	1	3,1959	0,3692	0,115523014	24,58384615
ZjuLEA-05	1	AT5G54370.1	5	37,2286	0,2754	0,007397538	286,3738462
ZjuLEA-05	1	AT4G27400.1	4	13,5971	0,3330	0,024490516	104,5930769
ZjuLEA-05	1	AT1G54890.1	1	8,9564	0,4062	0,045353044	68,89538462
ZjuLEA-05	1	AT5G60530.1	5	30,1448	0,5044	0,016732571	231,8830769
ZjuLEA-05	1	AT5G60520.1	5	49,1089	0,4936	0,010051131	377,7607692
ZjuLEA-05	1	AT3G19430.1	3	54,5870	0,59090	0,010824922	419,9
ZjuLEA-08	1	AT1G45688.1	1	50,7925	0,4931	0,009708126	390,7115385
ZjuLEA-08	1	AT3G24600.1	3	49,3062	0,6160	0,012493358	379,2784615
ZjuLEA-08	1	AT5G42860.1	5	46,3887	0,5181	0,011168668	356,8361538
ZjuLEA-09	1	AT1G52330.1	1	1,5145	0,4911	0,324265434	11,65
ZjuLEA-09	1	AT4G13270.1	4	4,8179	0,4918	0,102077669	37,06076923
ZjuLEA-09	1	AT1G52330.2	1	2,1340	0,5770	0,270384255	16,41538462
ZjuLEA-10	1	AT2G44060.2	2	4,6835	0,1568	0,033479236	36,02692308
ZjuLEA-10	1	AT2G44060.1	2	4,6841	0,1568	0,033474947	36,03153846
ZjuLEA-11	1	AT2G44060.2	2	4,6837	0,1568	0,033477806	36,02846154
ZjuLEA-11	1	AT2G44060.1	2	4,6839	0,1568	0,033476377	36,03
ZjuLEA-12	1	AT2G44060.2	2	4,6836	0,1568	0,033478521	36,02769231
ZjuLEA-12	1	AT2G44060.1	2	4,6834	0,1568	0,03347995	36,02615385
ZjuLEA-13	1	AT2G44060.2	2	4,6836	0,1568	0,033478521	36,02769231
ZjuLEA-13	1	AT2G44060.1	2	4,6838	0,1568	0,033477091	36,02923077
ZjuLEA-15	2	AT3G44220.1	3	47,9918	0,3864	0,008051375	369,1676923
ZjuLEA-15	2	AT3G11660.1	3	53,8475	0,4411	0,008191652	414,2115385
ZjuLEA-15	2	AT5G22200.1	5	19,5776	0,4003	0,020446837	150,5969231
ZjuLEA-15	2	AT5G06330.1	5	58,4695	0,4416	0,007552656	449,7653846
ZjuLEA-15	2	AT2G35960.1	2	55,1178	0,5004	0,009078737	423,9830769
ZjuLEA-15	2	AT3G52470.1	3	54,3270	0,5201	0,009573509	417,9
ZjuLEA-15	2	AT4G09590.1	4	57,0007	0,5785	0,010148998	438,4669231
ZjuLEA-15	2	AT2G35970.1	2	9,2790	0,5886	0,06343356	71,37692308
ZjuLEA-16	2	AT2G27080.1	2	2,8952	0,3315	0,114499862	22,27076923

ZjuLEA-16	2	AT2G27080.2	2	2,8953	0,3315	0,114495907	22,27153846
ZjuLEA-16	2	AT5G21130.1	5	2,4056	0,5085	0,211381776	18,50461538
ZjuLEA-17	2	AT2G27080.1	2	2,8953	0,3315	0,114495907	22,27153846
ZjuLEA-17	2	AT2G27080.2	2	2,8952	0,3315	0,114499862	22,27076923
ZjuLEA-17	2	AT5G21130.1	5	2,4056	0,5085	0,211381776	18,50461538
ZjuLEA-21	2	AT5G60530.1	5	3,6526	0,3005	0,082270164	28,09692308
ZjuLEA-21	2	AT5G60520.1	5	3,1582	0,2303	0,072921284	24,29384615
ZjuLEA-21	2	AT4G27400.1	4	51,1279	0,5274	0,010315307	393,2915385
ZjuLEA-21	2	AT5G54370.1	5	4,9119	0,5651	0,11504713	37,78384615
ZjuLEA-21	2	AT1G54890.1	1	11,7441	0,5378	0,045793207	90,33923077
ZjuLEA-21	2	AT3G19430.1	3	55,6488	0,6936	0,012463881	428,0676923
ZjuLEA-22	2	AT3G44380.1	3	2,1264	0,1798	0,084556057	16,35692308
ZjuLEA-23	2	AT3G22490.1	3	40,8769	0,3842	0,009398951	314,4376923
ZjuLEA-23	2	AT3G22500.1	3	40,7638	0,4223	0,010359682	313,5676923
ZjuLEA-28	3	AT5G53730.1	5	2,8131	0,2780	0,098823362	21,63923077
ZjuLEA-29	4	AT2G01080.1	2	4,1884	0,2472	0,059020151	32,21846154
ZjuLEA-30	4	AT5G36970.1	5	4,6606	0,3506	0,075226366	35,85076923
ZjuLEA-30	4	AT1G65690.1	1	4,8801	0,3320	0,068031393	37,53923077
ZjuLEA-30	4	AT1G54540.1	1	16,2181	0,5329	0,03285835	124,7546154
ZjuLEA-33	5	AT1G54540.1	1	3,3714	0,3525	0,104555971	25,93384615
ZjuLEA-33	5	AT5G36970.1	5	2,4691	0,3972	0,160868333	18,99307692
ZjuLEA-33	5	AT1G65690.1	1	4,0303	0,3972	0,098553458	31,00230769
ZjuLEA-34	5	AT1G54540.1	1	3,3980	0,3494	0,102825191	26,13846154
ZjuLEA-34	5	AT5G36970.1	5	2,3522	0,4034	0,171499022	18,09384615
ZjuLEA-34	5	AT1G65690.1	1	3,4702	0,4035	0,116275719	26,69384615
ZjuLEA-35	6	AT1G45688.1	1	4,3493	0,2141	0,049226312	33,45615385
ZjuLEA-35	6	AT5G42860.1	5	2,6598	0,2464	0,092638544	20,46
ZjuLEA-35	6	AT1G45688.2	1	13,7242	0,2095	0,015265006	105,5707692
ZjuLEA-38	7	AT3G22490.1	3	17,813	0,2516	0,014124516	137,0230769
ZjuLEA-38	7	AT3G22500.1	3	40,3235	0,2922	0,007246395	310,1807692
ZjuLEA-40	8	AT2G46150.1	2	2,08164	0,3856	0,185238562	16,01261538
ZjuLEA-41	8	AT4G01410.1	4	4,6628	0,4412	0,094621258	35,86769231
ZjuLEA-42	8	AT4G01410.1	4	4,6627	0,4412	0,094623287	35,86692308
ZjuLEA-43	8	AT4G01410.1	4	4,5570	0,3875	0,085034014	35,05384615
ZjuLEA-44	8	AT4G01410.1	4	4,5569	0,3875	0,08503588	35,05307692
ZjuLEA-45	8	AT1G45688.1	1	3,6651	0,2824	0,077051104	28,19307692
ZjuLEA-45	8	AT5G42860.1	5	4,1567	0,3164	0,076118074	31,97461538

ZjuLEA-45	8	AT1G45688.2	1	8,9626	0,2750	0,030683061	68,94307692
ZjuLEA-49	9	AT3G22490.1	3	10,5318	0,3604	0,034220171	81,01384615
ZjuLEA-49	9	AT3G22500.1	3	18,7711	0,3936	0,020968404	144,3930769
ZjuLEA-50	9	AT3G62580.1	3	2,1320	0,1168	0,05478424	16,4
ZjuLEA-51	10	AT3G26350.1	3	22,5589	0,5311	0,023542815	173,53
ZjuLEA-51	10	AT1G13050.1	1	3,5734	0,5617	0,157189232	27,48769231
ZjuLEA-51	10	AT1G13050.2	1	3,1249	0,3669	0,117411757	24,03769231
ZjuLEA-57	11	AT5G45320.1	5	51,1377	0,3666	0,007168879	393,3669231
ZjuLEA-60	12	AT3G24600.1	3	2,3343	0,5477	0,234631367	17,95615385
ZjuLEA-61	12	AT4G13270.1	4	3,7012	0,3581	0,096752405	28,47076923
ZjuLEA-65	12	AT2G35980.1	2	17,7180	0,4418	0,024935094	136,2923077
ZjuLEA-66	12	AT3G11660.1	3	36,0852	0,2414	0,006689723	277,5784615
ZjuLEA-66	12	AT3G52470.1	3	59,9217	0,2527	0,00421717	460,9361538
ZjuLEA-66	12	AT2G35960.1	2	37,6803	0,2718	0,007213318	289,8484615
ZjuLEA-66	12	AT3G44220.1	3	33,4892	0,2959	0,008835684	257,6092308
ZjuLEA-66	12	AT5G06330.1	5	47,1461	0,2887	0,006123518	362,6623077
ZjuLEA-66	12	AT5G22200.1	5	2,7797	0,3705	0,133287765	21,38230769
ZjuLEA-66	12	AT2G35970.1	2	61,5354	0,3723	0,006050176	473,3492308
ZjuLEA-66	12	AT4G09590.1	4	61,6527	0,3725	0,006041909	474,2515385
ZjuLEA-67	12	AT2G35980.1	2	48,8477	0,3540	0,007247015	375,7515385
ZjuLEA-67	12	AT3G11650.1	3	2,1927	0,4626	0,210972773	16,86692308
ZjuLEA-67	12	AT5G06320.1	5	61,0815	0,3833	0,006275222	469,8576923
ZjuLEA-67	12	AT2G35460.1	2	58,9563	0,5081	0,008618248	453,51
ZjuLEA-73	NW	AT4G26490.1	4	4,2939	0,3328	0,077505298	33,03
ZjuLEA-73	NW	AT5G56050.1	5	2,6475	0,3862	0,145873466	20,36538462
ZjuLEA-88	NW	AT1G72100.1	1	9,2716	0,5767	0,062200699	71,32
ZjuLEA-93	NW	AT3G11660.1	3	36,2633	0,2414	0,006656868	278,9484615
ZjuLEA-93	NW	AT3G52470.1	3	59,9135	0,2526	0,004216078	460,8730769
ZjuLEA-93	NW	AT2G35960.1	2	37,2470	0,2719	0,007299917	286,5153846
ZjuLEA-93	NW	AT3G44220.1	3	32,7745	0,2959	0,00902836	252,1115385
ZjuLEA-93	NW	AT5G06330.1	5	50,8205	0,2887	0,005680778	390,9269231
ZjuLEA-93	NW	AT5G22200.1	5	2,7797	0,3705	0,133287765	21,38230769
ZjuLEA-93	NW	AT2G35970.1	2	61,5368	0,3722	0,006048413	473,36
ZjuLEA-93	NW	AT4G09590.1	4	61,6591	0,3722	0,006036416	474,3007692
Mean				21,15	0,37	0,06	162,69

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Evaluation of Municipal Water Distribution Network Using Watercard and Watergems

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ABSTRACT

The pressure exerted on a water distribution system due to population increase and aging of the system amounts to routine assessment of its functionality. waterCAD and waterGEMS software was used comparatively in evaluating the serviceability of the water distribution system of Federal University of Agriculture Makurdi. A steady state analysis was also carried out to determine hydraulic parameters such as pressure, velocity, head loss, and flow rate. The result of the statistical analysis revealed that both simulators can be used interchangeably since there were no statistical differences. The pressure result indicated low head within the system which resulted to (100 %) of the nodes operating below the adopted system pressure of 10 meters. Also, (85 %) of the system velocity was within the range of 0.2 – 3 m/s adopted while 15% of the velocity exceeded the adopted velocity. The resultant effect of very high velocities in the system accounted for the pipe burst and leakages detected within the system. Hence, the system requires strengthen for optimum performance.

Anahtar Kelimeler:
ANOVA,
Karşılaştırmalı analiz,
Hidrolik Parametreler,
WaterCAD,
WaterGEMS.

ÖZ

Nüfus artışına ve sistemin yaşlanmasına bağlı olarak bir su dağıtım sistemine uygulanan baskı, işlevselliğinin rutin değerlendirmesine eşittir. WaterCAD ve waterGEMS yazılımı, Federal Tarım Üniversitesi Makurdi'nin su dağıtım sisteminin servis edilebilirliğinin değerlendirilmesinde karşılaştırmalı olarak kullanılmıştır. Basınç, hız, kafa kaybı ve akış hızı gibi hidrolik parametreleri belirlemek için bir kararlı durum analizi de gerçekleştirilmiştir. İstatistiksel analizin sonucu, her iki simülatörün birbirinin yerine kullanılabileceğini, çünkü istatistiksel farklılık olmadığını ortaya koymuştur. Basınç sonucu, sistemdeki düşük basma yüksekliğini gösterdi, bu da kabul edilen 10 metrelik sistem basıncının altında çalışan düğümlerin (% 100) sonucunu verdi. Ayrıca, sistem hızının (% 85) kabul edilen 0.2 - 3 m / s aralığındayken, hızın% 15'i kabul edilen hızı aşmıştır. Sistemdeki çok yüksek hızların sonuçta ortaya çıkan etkisi, sistemde tespit edilen boru patlaması ve kaçakları açıklamıştır. Bu nedenle, sistem optimum performans için güçlendirmeyi gerektirir.

1. Introduction

Drinking water serves as an essential element for life's sustenance and is also a required fundamental element with which almost all biotic components carry out their different activities of life [1]. As such, it is needful to pay close attention to the means via which this water is conveyed to consumers at their various stop taps. One of the most predominant factors affecting the performance of an existing network is the increase in population and its associated demand requirements which may call for complete reticulation or rehabilitation of the existing system. In evaluating the efficiency of a water distribution system, the design forms an integral part of the water supply setup which contributes enormously to curbing expenditures incurred during procurement and construction [2]. Hence, the need for a systematic design to achieve optimum system performance. Effective water supply in this instance is of major importance in the design of a new water distribution network, expanding of the existing network or strengthening it. The objectives attributed to a distribution system are to supply water to every household, industrial plants, and public places by means of a piping system at sufficient quantity and adequate pressure, without compromising its quality [3].

Agunwamba et al. [4] defined a water distribution system as ‘a system that supplies water with good quality, adequate quantities and at sufficient pressure to meet system requirements to the users’. Water distribution systems are required to supply water at a stipulated pressure based on the consumer’s demands which varies throughout the day, week, month and year. According to AWWA [5], the minimum pressure that should be observed at junctions throughout the system varies, and this depends on the type of water consuming sector and regulations that govern the system which typically operates between 275800 - 689500 N/m². However, the design of a water distribution system (WDS) and how it supplies water to users and its layout is related to their performance. A water distribution system (WDS) can be designed to supply water to its users through gravity flow, mechanical pumping or both. A system of water supply during its entire life should be able to provide the required quantity of water for the expected loading conditions with the desired residual pressures at all nodes. With the installation of distribution reservoirs and elevated tanks within different supply zones, some consumers are still left with little or no water supply [5]. Since water distribution systems are mostly designed and constructed to function for a long period of time, factors that affect the future performance of the system must be taken into cognizance. Some of these factors are population increase, the need for system expansion, pipe length, diameter, and pump capacity etc.

Water pollution, which has a negative impact on the quality of life of the society, is increasingly reaching to threatening dimensions [7]. One amongst the most disturbing issues faced by consumers of water in some part of the world is the unavailability of quality water and also the quantity of water that reach consumers at various supply outlets. According to Neelakantan et al [8] the problems generally faced with a water distribution system (WDS) arise from the following categories; (i) designing a new network (ii) modifying or expanding an existing network, (iii) operating an existing system.

Other problems faced with a water distribution system (WDS) are: increased service connections than estimated, expansion of service areas, breakage of network distribution components and increased roughness of pipe surface as a result of ageing. This study is aimed at evaluating the functionality of the water distribution network of Federal University of Agriculture, Makurdi using WaterCAD and WaterGEMS simulators. This will help to understand the needs of the system and also assist in the improvement of the long term planning of its utilities.

2. Material and Method

Study Area

The study was carried out at Federal University of Agriculture, Makurdi (FUAM). This University is a higher education institution that is located in Makurdi, Benue State, Nigeria. The University lies at latitude 7° 44´ North and Longitude 8° 35´ East of the Middle Belt region of Nigeria and it covers a land mass of 7,978 km². It is bounded on the North East by Guma Local Government Area and by River Benue in the South. Topographically, it is located in the Middle belt region of Nigeria and is characterized by gentle hills, clay soils, and tropical climate with two main seasons (rainy and dry seasons).

Figure 1. Google Earth Map of Federal University of Agriculture Makurdi

Data Collection

To assign demand to each node, the following components were taken into consideration; population demand, minor losses, fire demand and unaccounted for water. Population demand refers to the amount of water that is extracted from a particular node by that population served by that node [4]. Unaccounted for water consists basically of two components: water lost from the system and water used but not sufficiently documented [9]. Linkungan [10] stated that a provision of 10% of the population demand is added as fire demand in the case of fire outbreak. A 5% provision for minor losses is given. This accounts for losses where there are bends, valves, and fittings. Some other details required for the hydraulic simulation are Population served, Total pipe length, Demand per capita and Daily peak factor given as 29,121, 8,779 m, 120 l/c/d and 1.5, respectively. Table 1 shows the analysis of nodal demands at each node.

Table 1. Analysis of Demands at the Distribution Network Nodes

Node ID	Name	Population	Lcpd	Daily Demand (l/day)	Demand (l/s)	Fire Demand 10%	Minor Losses 5%	UFW 15%	Total Nodal Drawoff (l/s)
1	Meg Icheen Hall.	616	120	73920	0.86	0.09	0.04	0.13	1.12
	Block B	616	120	73920	0.86	0.09	0.04	0.13	1.12
	DTH Hall	616	120	73920	0.86	0.09	0.04	0.13	1.12
	Block C	180	120	19200	0.22	0.02	0.01	0.03	0.28
2	Gauis IgboeliBldg	5342	120	641040	7.42	0.74	0.37	1.11	9.64
3	Block A	5221	120	626520	7.25	0.73	0.36	1.09	9.43
4	Senior Staff Qtrs	840	120	100800	1.17	0.12	0.06	0.18	1.53
7	FST Cmplx	3028	120	363360	4.21	0.42	0.21	0.63	5.47

8	Engr'ring Cmplx	2420	120	290400	3.36	0.34	0.17	0.50	4.37
9	Zamfara Hostel	616	120	73920	0.86	0.09	0.04	0.13	1.12
	Block E	616	120	73920	0.86	0.09	0.04	0.13	1.12
	Block F	616	120	73920	0.86	0.09	0.04	0.13	1.12
10	Mgt. Sc.	1300	120	156000	1.81	0.18	0.09	0.27	2.35
11	Agronomy	1986	120	238320	2.76	0.28	0.14	0.41	3.59
	Agric. Ext	1988	120	238560	2.76	0.28	0.14	0.41	3.59
12	PG Sch	340	120	40800	0.47	0.05	0.02	0.07	0.61
14	Animal Sciences	1915	120	229800	2.66	0.27	0.13	0.40	3.46

KEY: UFW = Unaccounted-for-water

WaterGEMS and WaterCAD Simulators

WaterGEMS V8i provides a friendly interface for engineers to analyze, design and optimize water distribution systems. This software manages the water system data, time-series hydraulic result, current and future scenarios and other core infrastructure data all within the same GIS environment [11]. Also, according to [12] network variables such as; flow, pressure, and velocity along with their optimization can be controlled because waterGEMS V8i has strong design algorithm for accurate design of the network.

WaterCAD is a hydraulic software and water quality modeling application for water distribution systems. waterCAD helps engineers and users to analyze, design and optimize water distribution systems. It is developed by the Bentley company and has the following capabilities; Building a network and performing a steady state analysis, Extended period simulations (EPS), Interface and graphical editing, Streamlined model building, Water quality analysis, Automated Fire flow analysis, Reporting results, Pressure dependent demand, Darwin designer to optimize a pipe network, Critical and segmentation and Comprehensive scenario management.

3. Results

Table 2 shows the result of flow rate (l/s), velocity (m/s), and headloss (m) for both waterCAD and waterGEMS simulators. While Table 3 shows the result of pressure fluctuation within the distribution system.

Table 2. Pipe information/Pipe output data

Pipe	Start Node	Stop Node	Diameter (mm)	Length (m)	Flow (l/s)	Velocity (m/s)	Head loss (m)
1	R-1	Pmp-1	250	67.00	30	0.62	0.09
2	Pmp-1	CV-1	250	447.33	30	0.62	0.59
3	J-1	T-2	110	210.00	22	2.29	8.17
4	T-2	T-3	110	88.00	-36	3.79	8.66
5	J-1	J-2	250	305.00	6	0.12	0.02
6	J-2	T-4	110	71.00	-25	2.60	3.49
7	J-2	CV-2	250	61.14	23	0.47	0.05
8	J-3	T-5	110	83.24	-29	3.08	5.58
9	CV-2	J-3	250	50.40	23	0.47	0.04
10	J-3	J-4	250	1,301.00	45	0.92	3.56
11	J-4	CV-3	225	0.03	-25	0.64	0.00
12	CV-3	T-1	225	730.00	-25	0.64	1.16
13	J-4	J-5	250	636.26	69	1.41	3.88

14	J-5	CV-4	250	689.24	69	1.41	4.20
15	CV-4	J-6	250	62.45	69	1.41	0.38
16	J-6	CV-5	250	670.69	69	1.41	4.09
17	CV-5	J-7	250	32.05	69	1.41	0.20
18	J-7	T-6	225	149.00	48	1.20	0.76
19	J-7	J-8	225	350.00	-6	0.15	0.04
20	J-8	T-7	63	49.00	-10	3.05	6.20
21	T-7	CV-6	63	5.40	0	0.00	0.00
22	CV-6	T-8	63	4.60	0	0.00	0.00
23	J-8	CV-7	225	718.52	0	0.00	0.00
24	J-9	T-9	110	43.00	-29	3.08	2.89
25	CV-7	J-9	225	26.77	0	0.00	0.00
26	J-9	T-10	110	93.46	29	3.08	6.27
27	J-7	J-10	250	195.00	24	0.48	0.16
28	J-10	T-11	110	41.00	22	2.29	1.60
29	J-10	CV-8	250	540.06	0	0.00	0.00
30	CV-8	J-11	250	29.94	0	0.00	0.00
31	J-11	T-12	110	49.00	11	1.13	0.52
32	J-11	T-13	110	116.00	19	2.00	3.52
33	J-11	J-12	250	182.00	-35	0.72	0.32
34	J-12	T-14	110	53.00	-36	3.77	5.17
35	CV-1	J-1	250	18.67	30	0.62	0.02
36	J-12	CV-10	250	237.16	0	0.00	0.00
37	CV-10	J-13	250	27.84	0	0.00	0.00
38	J-13	T-15	110	54.00	16	1.67	1.16
39	J-13	J-14	250	773.00	-17	0.35	0.35
40	J-14	T-16	110	108.00	-20	2.07	3.49

KEY: CV= Check Valve; P = Pipe; J = Junction; T = Tank; Pmp = Pump; R = Reservoir

Table 3. Nodal elevation and Pressures result in waterCAD/waterGEMS

Junction	Elevation (m)	Pressure (m)
1	110.00	7.65
2	112.00	5.53
3	113.00	4.56
4	105.00	8.99
5	101.00	9.02
6	103.00	2.41
7	100.00	1.21
8	101.00	0.23
9	115.00	7.24
10	99.00	2.06
11	102.00	1.99
12	100.00	4.27
13	111.00	1.63
14	110.00	2.96

4. Discussion

Output of Nodal Demand (l/s) in waterCAD and waterGEMS

Figure 3 shows the result of nodal demand at various nodes for waterCAD and waterGEMS simulators. Nodes 2, 3, 7 and 11 are areas with particularly high draw-outs with nodes 2 and 3 having the highest demands. Nodal demands are mainly based on the population served by that particular node [4]. Nodes 2 and 3 happen to have the highest population which is evident in the amount of draw-outs at those nodes.

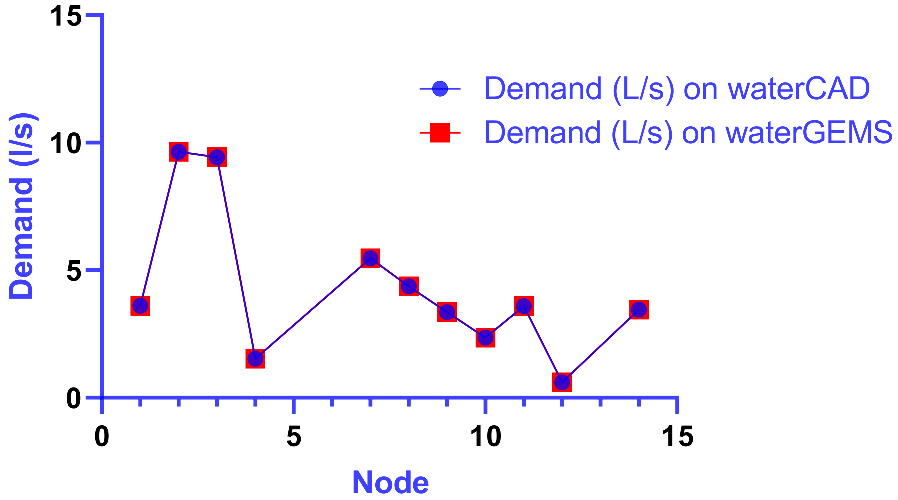

Figure 3. Nodal Demand Output in WaterCAD/WaterGEMS

Output of Flow Rate and Velocity Fluctuations in WaterCAD/WaterGEMS Simulators

The output result of velocity and flow rate at various pipes is presented in Figure 4 and 5, respectively. The velocity of flow including those greater than 3m/s were depicted with 6 out of the 40 pipes having velocities greater than 3.0m/s while others have their velocities within the range of 0.2m/s to 3.0m/s and some less. Very high velocities occurred in pipes 4, 8, 20, 24, 26 and 34 within the system. One of the parameters that should be considered when quality of water in a distribution system is altered is velocity [13]. For the distribution system under study, the most eminent causes of velocity fluctuation are: (i) Changes in demand (nodal draw-off), (ii) Changes in transmission conditions. Very high velocity changes in a distribution system can cause leakage, when there are pipe burst and subsequent entering of water into the system [14]. In other to maintain an adequate flow velocity in the system, the step-down approach should be employed. This will require a progressive decrease in the size of the pipes so that a higher flow velocity can be achieved in the entire loop or system. This would also help to maintain a consistent pressure throughout the system.

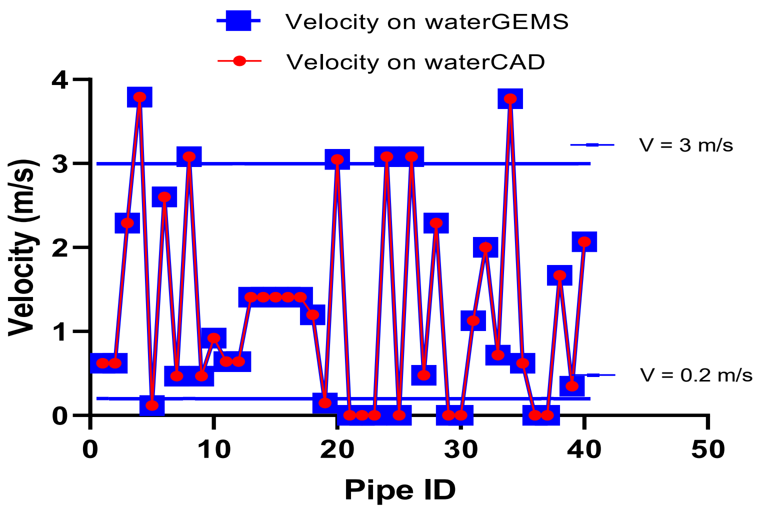

Figure 4. Results of Velocities in WaterCAD/WaterGEMS

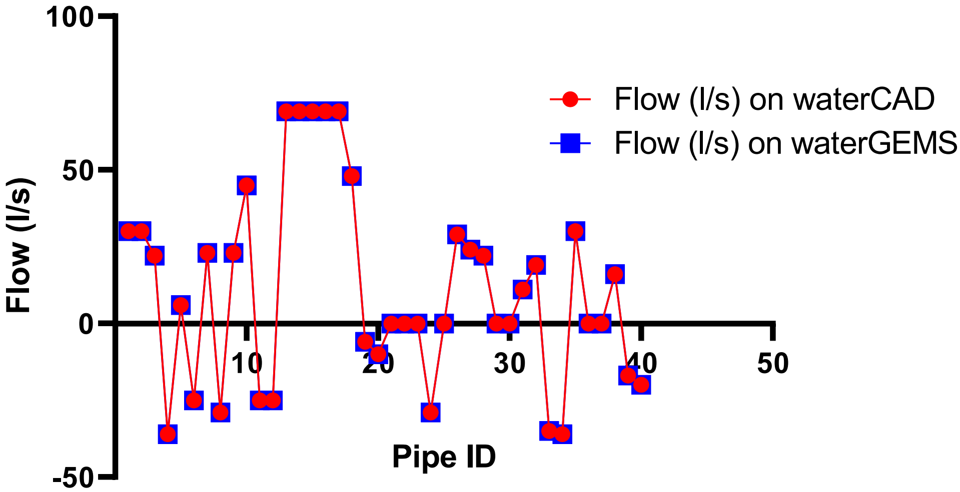

Figure 5. Results of Flow rate of waterCAD/waterGEMS Simulators

Pressure Fluctuations and Node Elevations in the System

Figure 6 shows the result of pressure distribution at various nodes and the elevation of the nodes within the distribution system for waterCAD/waterGEMS simulators while Figure 7 shows the contour plot of pressure distribution. The minimum pressure adopted for this study is 10m. Nodes J1 - J14 all fell below the minimum adopted system pressure. This indicates that the pressure within the distribution system is low and not sufficient enough for effective system performance. This can be attributed to a number of factors which include: (i) pipe roughness, (ii) leakages (iii) equipment failure, (iv) elevation.

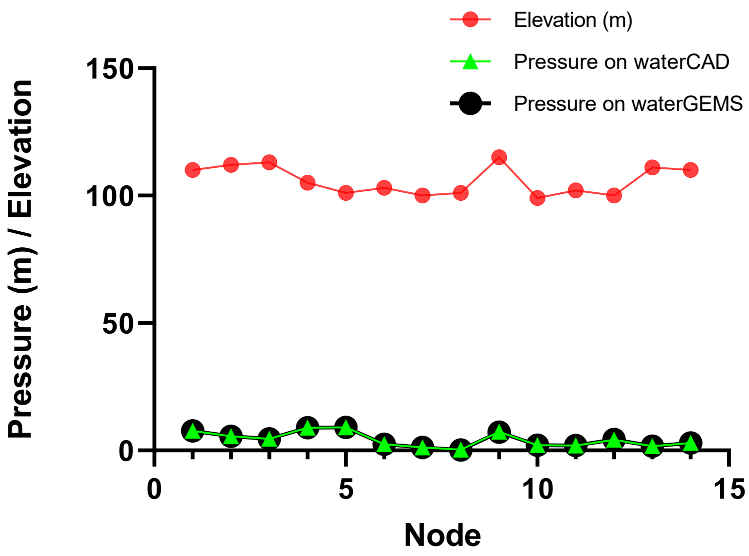

Figure 6. Result of Pressure and elevation at various nodes within the distribution system for waterCAD/waterGEMS simulators

Statistical Comparison of Results

Single Factor ANOVA test was used in comparing the level of significant difference in results obtained from both simulators. This test was carried out on pressure, velocity, and nodal demand results. Table 4 shows the summary of ANOVA test for results of pressure, nodal demand, velocity, and headloss obtained using waterCAD and waterGEMS simulators.

Table 4. Summary of ANOVA Result for waterCAD and waterGEMS Simulator

Parameter	Fcritical	F	P-value	Remark
Pressure	4.23	1.4xE-5	0.998	No significant difference in waterCAD and waterGEMS pressure output
Nodal demand	4.3	7.8xE-5	0.993	No significant difference in waterCAD and waterGEMS demand output
Velocity	3.96	2.4xE-4	0.988	No significant difference in waterCAD and waterGEMS velocity output
Headloss	3.96	1.9xE-4	0.99	No significant difference in waterCAD and waterGEMS headloss output

The results all showed that there was no statistically significant difference between velocity ($p = 0.988$), pressure ($p = 0.998$), nodal demand ($p = 0.993$) and headloss ($p = 0.990$) values obtained from both waterCAD and waterGEMS simulators at $\alpha = 0.05$. The system recorded an average value of 1.22 m/s for velocity, 3.38 m for pressure, 1.91 for headloss and 3.38 l/s for nodal demand. Eighty-five percent (85 %) of both waterCAD and waterGEMS velocity results were within the adopted range of 0.2 – 3 m/s while fifteen percent (15 %) of the velocity results violated the adopted velocity range. Pressure results for both waterCAD and waterGEMS recorded a hundred percent (100 %) value below the adopted system pressure of 10 m. The adopted system pressure was influenced by the height of buildings (10 m) within the location of study.

5. Conclusions

The focus of this study is to analyze the water distribution system of Federal University of Agriculture, Makurdi and to identify deficiencies (if any) that may be present in the system using waterCAD and waterGEMS simulators. There was pressure fluctuation in the system and this is as a result of elevation changes and draws out at the nodes. The system recorded insufficient pressure to meet the required demand at all the junctions. A number of pipes within the system recorded velocities within the adopted velocity; however, very high velocities were recorded at some points. Leakages and pipe burst were also noticed, hence requiring strengthening of the system for improved system performance.

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