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Abiotic Stresses and their Effects, Responses, and Adaptations in Grapevines (Vitis vinifera): Overview of Modern Research: a Review

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ABSTRACT

Grapevines are cultivated throughout the world and face environmental fluctuations due to changing climatic and abiotic conditions. Temperature stress, hormonal imbalance, salinity and drought stress are the most damaging abiotic stresses that affect the metabolic processes, physiological structure and yield of the plants. This review focuses on the recent advancement in the study of various abiotic stresses on grapevines, their responses and the development of tolerance in them. Grapevines are also very sensitive to these abiotic stresses and have adaptations such as increase in abscisic acid synthesis, ascorbate peroxide concentration and genes expression for the development of resistance to overcome the harsh environment. According to the recent research, the exogenous application of kaolin is very useful in the control of harmful effects of heat stress and hormonal imbalance in grapevines. The study of the different stable genes expression in grapevines under sanity drought and cold stress is also helpful in the synthesis of the most resistant transgenic plants. The further study of the application of the different protective chemicals on the grapevines under abiotic stresses will open new ways for their management. The future genetic study of grapevines for the identification of different reference genes will result in the synthesis of the most stable transgenic plants.

Keywords: grapevines, abiotic stresses, adaptations, kaolin, genes, transgenic plants

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1. Introduction

Grapes are one of the most important fruits of the world that are mostly cultivated in the temperate and sub-tropical region of the northern hemisphere and are used all over the world. Grapes are used for the purpose of wine industry, table fruit, juices, canning, drying and in medicines (Keller, 2015). According to the statistics of 2016 Food and Agriculture Organization of United Nations, more than 70% of the total world's grape production is consumed in the wine industry; other 27% of the fruit is used as fresh fruit and approximately 2-3% of the grapes are processed for juices, drying and canning purpose each year. The world largest producer of grapes is China followed by India, Turkey, European Union and the United State of America in total production share. World total grape's production is 77,438,929 tonnes from total harvesting area of 7,096,741 hectares and average yield from the total area is 109119 hg/ha (FAOSTAT, 2018). An understanding of the severity of abiotic stresses on the plants and their response under these unfavorable conditions help us to enhance the plants resistance. This review adds new information on the responses of grapevines under abiotic stresses and the enhancement of resistance under stressful conditions.

1.1 Botany of grapes

Grapevines belong from the kingdom Plantae and are studied under phylum Angiospermae, which further classify grapes into class Dicotyledonae. The grape's order is Rhamnales (Vitales) and family is Vitaceae. The members of Vitaceae family are collectively called as grapevine that is why grapes are commonly known as grapevines. The family Vitaceae has 17 genera and 1000 species. One of the most important genera of these seventeen is Vitis (2n = 38 Chromosomes). Commercially, there are three main species of grapes that are mostly cultivated because of their fruit quality all over the grape growing regions of the world. European grape (*Vitis vinifera*) is characterized by the thick skin and sweet pulp most suitable for the cultivation in the sub-tropical region. American grape (*Vitis labressca*) and Muscadine grape (*Vitis rotundifolia*) are more suitable for cultivation in the temperate region because of their high chilling hour's requirement to break bud dormancy. Both these species have fruits with acidic pulp along with the thin skin. Grapevines have compound bud bearing on one year old canes. Flowers are complete perfect and fruit is a true berry, which maybe seeded or seedless (Keller, 2015).

1.2 Categorization of plant stresses

Plant stresses are basically categorized into two types: biotic stresses and abiotic stresses. The causes of abiotic stresses are other than the living organisms such as unfavorable environmental conditions, very low or high temperature, drought, flood, wind storms, frost, salt and hormonal stresses. While biotic stresses are related to the living organisms such as attack of insects, viruses, bacteria, fungi, nematodes and weeds (Skirycz and Inze 2010). All these biotic and abiotic stresses affect the plant metabolic processes, physiological structure and yield adversely. These adverse effects directly influence the economic yield of plants (Jan et al., 2017). Plants have developed adaptation mechanism that enables them to survive these harmful conditions. Such metabolic adaptations are stomatal regulations under drought conditions and dormancy to avoid from extreme temperature. Abiotic stresses activates genes in plants that make them strong enough to survive unfavorable environment (Skirycz and Inze, 2010; Seo et al., 2009). Plants have different mechanisms to produce chemicals such as antioxidants and antimicrobial compounds to survive under biotic stresses such as under the attack of bacteria and viruses (Lee et al., 2016; Lin et al., 2015; Muhammad et al., 2015).

2. Abiotic stresses and plants: General Overview

Plants have metabolic processes such as respiration, photosynthesis and transpiration that are very sensitive even for short term environmental fluctuations. Photosynthesis is the most important and critical process in plants that is directly or indirectly affected by abiotic stresses. Abiotic stresses are the cause of denaturing of protein RuBisCO (Calvin cycle enzyme) and damage Photosystem II that limits the photosynthesis and results in plant death (Nishiyama and Murata, 2014). Generally, abiotic stresses affect all the plants on earth and plants in result show adaptations for their survival.

2.1 Temperature stress and plant Adaptations

One of the most destructive abiotic stresses that economically damage the crop yield all over the world is temperature fluctuation. Temperature above or below the optimum level affect the plant metabolic processes and its physiological structure especially during its younger age when the plant has not developed enough resistance to survive this critical state (Ismaili et al., 2015). The damages that are caused by the low or high temperature stress depend upon the plant species or cultivars and also upon the magnitude and intensity of stress. Some cultivars have ability to survive harsh conditions better as compared to others (Zhang et al., 2015). Due to high temperature, plant mechanism for chlorophyll synthesis is disturbed and causes the reduction of chlorophyll contents mostly in seedlings and immature plants (Gupta et al., 2013; Shah et al., 2015). Plant transpiration rate increases due to high temperature and causes the disturbance in stomatal regulations, which will reduce the ATP synthesis under reduced chlorophyll pigment (Sing et al., 2014; Oh et al., 2014).

Low temperate along with the frost during winter causes the death of the plant if temperature falls below the tolerance. Under chilling stress, seed germination is decreased and seedling growth is suppressed that will start the necrosis and wilting of the plant. This will cause the maximum loss of water from cell and plant death (Shah et al., 2016; Fiebelkorn and Rahman, 2016). Plants have developed mechanisms to combat these abiotic stresses. Plants under temperature stress increase the production of an enzyme 'Ascorbate peroxidase' and genes expression. Due to up-regulation of this enzyme and genes expression, plants have resistance to survive harsh weather. Under high temperature, production of an amino acid 'Proline' also increases that has ability to save the proteins from denature and prevent cell death (Claussen, 2005; Sato et al., 2011; Ismaili et al., 2015).

2.3 Drought stress and plant adaptations

Drought stress is also an unfavorable condition that plants face under water deficit and high temperature during their growth and development. Water deficit is the situation when plant has not sufficient water to fulfill their water demand. Plant structural changes result due to water stress such as change in thylakoid membrane structure that reduces the efficiency of chloroplast and decreases photosynthesis rate (Ashraf and Harris, 2013). Various parts of plants are affected at different rate under water deficit. Drought affects the biosynthesis of an organic polymer lignin that is the integral component of most of the plants cell wall. Some plant parts produce more lignin than others such as basal part of the plants root produce more lignin as compared to terminal portion under drought. Due to more lignin, basal root cells become stiff; cell expansion and growth stops. While terminal root portion continues to grow deep into the soil in search of water and nutrients to overcome these stressful conditions (Lestari et al., 2018).

According to IPCC (2014), water shortage will be the most destructive factor for life on earth so plants need adaptations to survive these climatic changes (Zandalinas et al. 2016a; Zandalinas et al. 2016b).Under drought conditions, rate of respiration in plants increases and plants have adopted to change the stomatal structure and regulations to overcome the damages. One of the most important examples of this adaptation is CAM plants (Mittler and Blumwald, 2010). The increase in APX enzyme and genes expression under drought stress is also helpful for the survival of the plants (Cruz et al., 2013; Pandey et al., 2017). So, these expressed genes are studied for survival of plants under various stresses and transgenic plants are produced to face abiotic stresses (Zandalinas et al., 2018).

2.4 Light and radiation stress

The major source of light on earth is sun-light. Sun emits radiations at different wavelengths and frequencies. These radiations are categorized into different groups on the basis of these wavelengths. The most important light spectrum for plants is the visible light (400-700nm). This light spectrum is also called as photosynthetically active radiation (PAR) that plants use during photosynthesis. But the most destructive radiations for structural and metabolic survival of the plants are ultra violet radiations (200-400nm).Mostly the UV-rays are absorbed by the stratospheric ozone layer but from past few decades, due to splitting of the ozone layer these rays are approaching the earth surface and causing damage to the plants (Tripathi et al., 2017). When light frequency increases then plant cells start degeneration due to activation of reactive oxygen species (ROS).

UV-rays cause the reduction in Photosystem antenna contents that will decrease the photosynthesis in plant. Moreover the UV-B radiations (280-320nm) will increase ethylene production in plants that will cause leaves and fruits abscission and death of the plants. Plants have adaptive mechanism to produce more Abscisic acid (ABA) under increased UV-B rays. ABA will inhibit the ethylene activity and degeneration of ROS to protect the plant death (Li et al., 2014).When frequency of light increases, plants undergo the reduction of antenna system and this will reduce the absorption of light energy by wasting most of its frequency. Plants will start increase in synthesis of APXs and lignin to prevent the activity of ROS and lignin will make the cell wall rigid for survival of the harsh environment (Moura et al., 2010). APXs increased production will also combats the degeneration of proteins of mitochondria and chloroplast under high UV-B radiations (Maruta et al., 2010; Pandey et al., 2017).

2.5 Salt stress and Hormonal imbalance

Salt stress has adverse effects on plants and is the most critical because of the difficulty for the determination of this stress. When mineral contents increase in the soil or in irrigation water that adversely affects the plants than this situation is called as Salt stress (Guan et al., 2015; Hasanuzzaman et al., 2017). Salt stress affects the quality and the yield of the crops. It disturbs the uptake of water and nutrients in plants that will create a situation of drought stress and nutritional imbalance. Salinity also decreases the germination percentage and chlorophyll contents in plants and also enhances the ROS activity and disturbs the activity of plant metabolic enzymes. Due to these conditions, plants undergo adaptive mechanism (Chutipaijit et al, 2011). Salt stress will increase the production of APXs level that is an antioxidative enzyme, which inhibits the activity of ROS. This abiotic stress will cause genes expression, increase in proteins activity and changes in stomatal regulation within the plants and save them from damage during these situations (Diaz-vivanlos et al., 2013; Parihar et al., 2014).

Hormones are the substances that stimulate the growth and development of plants and also have significant role in maximum crop yield. Some important hormones are Auxins, Cytokinins, Gibberellins, Ethylene and Abscisic acid (ABA). The main functions of these hormones in plants are: Auxins enhance the roots growth; Cytokinins increase the shoots growth; Gibberellins regulate various developmental processes; Ethylene will cause abscission and ripening; and ABA breaks seed and bud dormancy. Under abiotic stresses, plants face hormonal imbalance that is damaging for them. ABA hormone is the most important growth regulator that prevents the plants from abiotic stresses and also called as "Stress Hormone". ABA inhibits the ethylene production and seizes the activity of ROS. Along with this, Abscisic Acid enhances the seed development, vegetative growth, sprouting and inhibits leaf abscission during salt stress (Peleg and Blumwald, 2011; Roychoudhury et al., 2015).

2.6 Heavy metal stress and Nutritional imbalance

Heavy metals are toxic for the plants that are taken up by them due to their presence in soil and irrigation water**.** These heavy metals are Al, Cd, Cu, Pb, Hg and Cr that enters into the environment through mining, burning, industry, waste seepage and fertilizers. These heavy metals affect the plants that results in the decrease of chlorophyll contents and inhibits stomatal opening thus reduces the photosynthesis (Moura et al., 2010). Plants that are under heavy metal stress show some genes expression that enables them to survive (Malar et al., 2014; Tripathi et al., 2016). Plant nutrients are necessary for different metabolic processes, growth, development, and are the component of different organs in plants. These nutrients are classified into Macro(Carbon, Hydrogen, Oxygen, Nitrogen, Phosphorus, Potassium, Calcium, Magnesium, and Sulfur) and Micro(Iron, Boron, Chlorine, Manganese, Zinc, Copper, Molybdenum, Nickel , and Sodium) nutrients according to their requirement for the plants. Deficiency and excess of these nutrients cause disturbance in plant growth and a long interval nutritional imbalance can cause the death of the plants. The nutritional balance at proper time can bring the plants back into their normal growth and development (Moura et al., 2010).

3. Interaction between Grapevines and Abiotic Stresses

Grapevines are equally sensitive and responsive to abiotic stresses like all other plants. The natural adaptation mechanism of the grapevines is also very slow like other plants when compared with the severity of the environmental fluctuations (Liu et al. 2012). A general view of some abiotic stresses like heat stress, hormonal imbalance, salinity, drought, and cold stress in grapevine is explained.

3.1 Heat stress and grapevines

We know that all the plants are sessile organisms. They have to face environmental fluctuations directly without any protective covering that cause disturbance in their normal life cycle. Heat stress is a condition when intensity of temperature increases above the threshold level of the plant tolerance, which causes an irreversible damage to them. Grapevines have internal adaptive mechanism to combat these stresses by changing their behavior from normal conditions within hours or days. Heat stress is considered most critical factor for grapevines because of their sensitivity to high temperature. When the temperature increases above the 35 ˚C, it disturbs the photosynthesis rate in grapevines. Normally the air temperature of the areas of grapevine production exceeds 40 ˚C. This will result in superior quality fruit and decreases the grape's yield in these regions if plants are facing these conditions without internal adoptions and external management for the tolerance in grapevines. Grapevines undergo developmental changes such as budburst, flowering, verasion and also fruit burn under high temperature stress (Liu et al. 2012; Torregrosa et al., 2017).

Grapevines are grown in the region where temperature exceeds during fruit maturity above 40 ˚C. So, these have to face temperature above the optimal level. This will create disturbance in growth, development, metabolic processes and in the yield of the grapevines. A genetic study is very important because of the gene expression mechanism of grapevines under heat stress for their tolerance

(Carvalho et al., 2015; 2016). Different changes are observed under high temperature in the berry of grapevines. These changes are the increase in malic acid respiration that decreases the acidity and increases the sugar and alcoholic contents. This will increase the susceptibility of berries to microbial attack (Orduna, 2010).

3.2 Hormonal imbalance in grapevines

Hormones are directly involved in the growth and the different developmental stages such as bud sprout, flowering, fruit setting, fruit maturity and ripening of grapes. Under stressful conditions, plants have to face hormonal imbalance that make difficulties for their survival. During abiotic stresses, ABA is very important hormone that is also called as stress hormone for the resistance of grapevines to abiotic stresses. Exogenous application of ABA enables grapevines to resist the abiotic stresses. It will inhibit ethylene production and leaf abscission and also slows down the ripening (Koyama et al., 2010).

3.3 Salt stress on grapevines

The sensitivity of grapevines to the salinity makes them difficult to grow even in slightly saline soil or irrigation water. Salt stress has adverse effect on the physiology of grapevines. It causes permanent drought situations and difficulty for the roots to uptake the nutrients from the soil and transport to the other parts. This situation will cause loss in yield (Jellouli et al., 2010). Salt stress is actually associated with the accumulation of Na^+ and Cl^- ions in root zone of grapevines that are very sensitive for Na^+ accumulation. Na^+ ions adversely affect many biological processes in grapevines and causes death. The adaptation in grapevines for the tolerance to salinity includes reduction in ion absorption, transport of ions from roots to other parts and reduction in photosynthesis for the survival under salinity (Walker et al., 2010; Baneh et al., 2014).

3.4 Drought stress and Grapevines

It is predicted that after 50 years, drought will be the most damaging factor on agricultural farms. Water deficit is the most threatening condition for grape growers and has deleterious effects on crop yield and physiology (Haider et al., 2017). Grapevines survive the low water availability and short term water drought condition. But the long term drought conditions create difficulty for agronomic practices and water availability for grapevines during fruit setting and maturity period (Lovisolo et al., 2010; Ghaderi et al., 2011). Water deficit also affects the quality and quantity of fruit (Romero et al., 2015). The grapevines develop the control of the circulation of water toward leaves, stomatal conductance and aquaporin. These adjustments affect the leaf size; shoot growth and decline in diameter of xylem vessels (Escalona et al., 2013).

3.5 Cold Stress on grapevines

Chilling injury is also associated with the grapevines under very low temperature. Only low chilling varieties are grown in these areas of low temperature. Under cold stress, grapevines change their soluble sugar concentration; enhance Proline synthesis, modify proteins, increases antioxidants, phenolic compounds and ABA concentration for defense against very low temperature (Ershadi et al., 2016; Karimi et al. 2017).

4. Modern research: Tolerance to abiotic stresses in Grapevines

Grapevines are grown in the region where the temperature fluctuations during their life period cause different physiological changes that adversely affect the yield and stability of vines (Fraga et al., 2014). Due to these fluctuating conditions, grapevines change the size of their leaves, regulate IAA and ABA concentration. ABA inhibits the activity of ROS, regulates the growth and photosynthesis by developing resistance against abiotic stresses (Hassison, 2012; Danquah et al., 2014). IAA concentration in grapevines is also regulated through adaptations under climatic stresses to overcome the damage of harsh environment (Du et al., 2013).

4.1 Temperature, water potential and hormonal regulation through Kaolin

Kaolin ($Al_2H_4O_9Si_2$) is an odorless white clay mineral that develops tolerance against abiotic stresses in grapevines because it results in hormonal regulation, temperature reduction and increase in water potential of plants. It protects the plants from UV-radiation through reflecting most of the frequency without disturbing the absorption of PAR by leaves for photosynthesis in grapevines (Song et al., 2012; Conde et al., 2016). Grapevines are treated with kaolin for studying its effects in temperature reduction, hormonal regulation and increase in water potential of leaves in them. A 5% w/v of kaolin is applied in the test series of grapevines for a comparison with control series (without treated with kaolin) under same climatic conditions. Leaves are taken as sample for measuring the changes in water potential, hormonal concentration and temperature due to the treatment through kaolin (Dinis et al., 2016a; Dinis et al., 2016b).

Water potential of the leaf sample is taken two times during the experiment one just after a week of kaolin application (July) and other after one month (August) with two intervals predawn (ψ_{pd}) and midday (ψ_{md}) (Dinis et al., 2018). When we notice the water potential just after a week of kaolin application, the finding of predawn and midday water potential shows negligible difference between control and test series. But the results after a month shows an increase in predawn and midday water potential of leaves in grapevines up to 30 and 17 % respectively as shown in Fig. 1. Kaolin treated leaves also showed reduction in temperature ranging from 8.5-13.8% during the experiment.

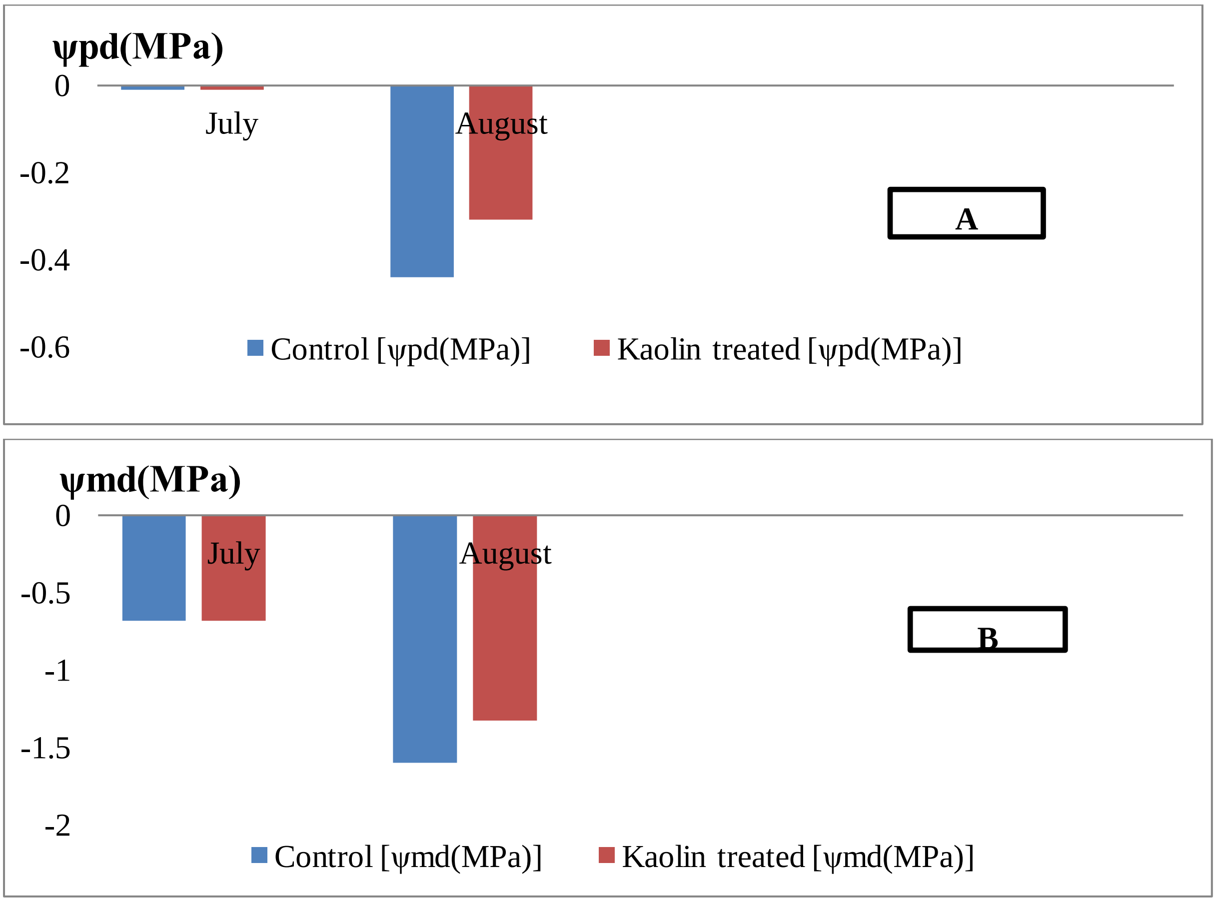

Fig. 1: Predawn (ψ_{pd}) = A; midday (ψ_{md}) = B

When ABA and IAA concentration in the leaves of kaolin treated grapevines is calculated, it shows a significant reduction of ABA and an increase in IAA concentration as compared to control series of grapevines after one month of treatment shown in Fig. 2. This reduction in ABA and increase in IAA helps the plant in maintaining their growth and development under stressful conditions

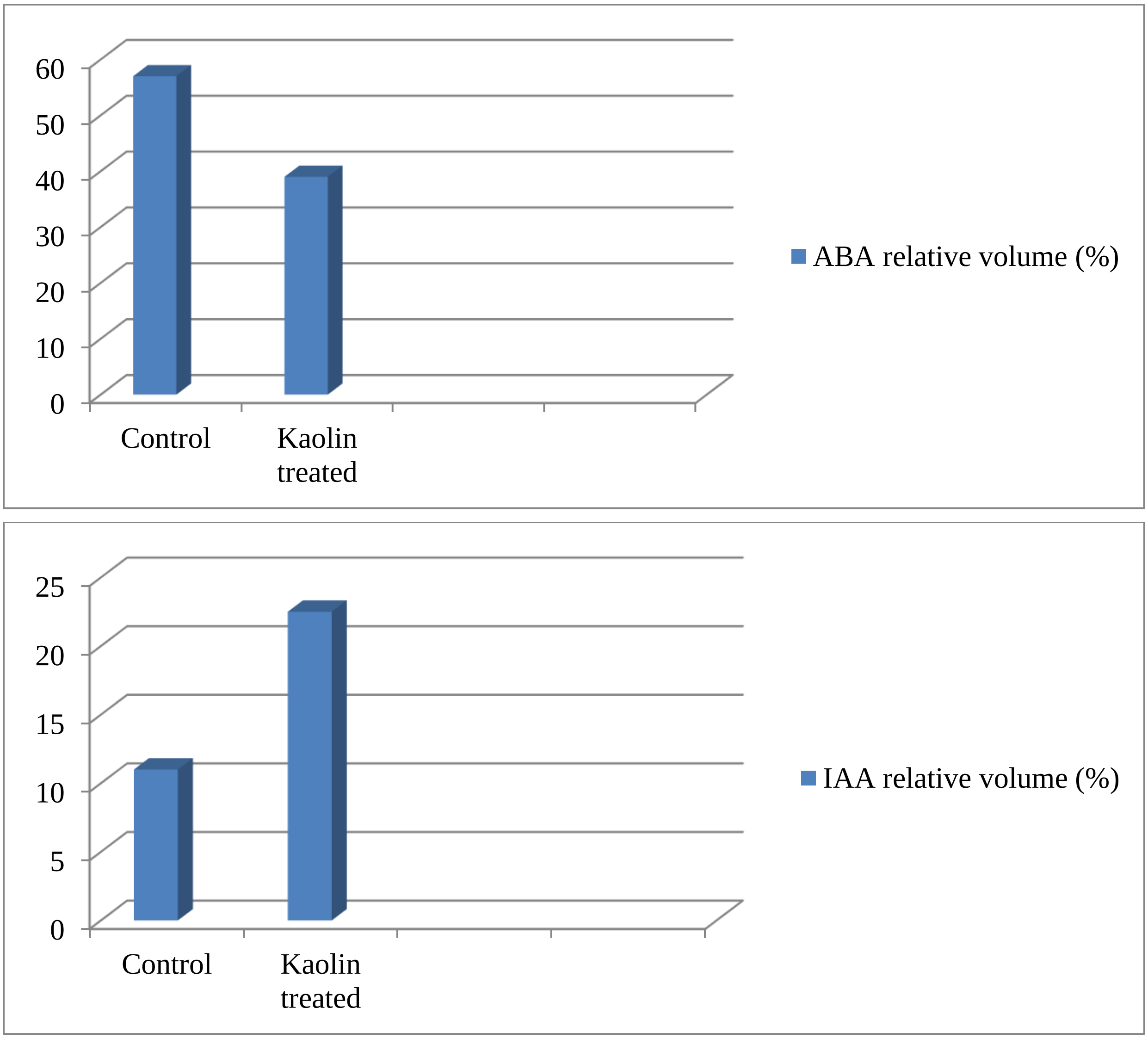

Fig. 2: Indole-3-acetic acid (IAA) and Abscisic acid (ABA) concentration in kaolin treated leaves and control series collected after one month in the afternoon period.

4.2 Gene expression under salinity, drought and cold stress: (miRNA) qRT-PCR technique

MiRNA also known as micro RNA is approximately 20 nucleotides RNA molecule that enables the plants to stabilize their physiology and metabolic processes under abiotic stresses. The study of MiRNA is very difficult because of its extra short length. The study is done through RT-PCR technique in which RNA transcripts in to DNA through reverse transcriptase and then DNA is used as template for PCR (Chen et al., 2011). Abiotic stresses like salinity, drought and cold can cause damage to the cellular structure and metabolic processes of grapevines due to the activation of ROS and many other changes. Under abiotic stresses, gene expression is considered an important adaptation for the development of resistance and survival of plants. MiRNA is considered a key regulatory factor that maintains growth and development of grapevines under abiotic stressful conditions (Hackenberg et al. 2015; Schwarzkopf and Piecce, 2016).

This study enables us for the understanding of resistance development in grapevines under salinity, drought and cold stress by measuring the stability of reference genes of MiRNA. qRT-PCR is a technique which is used for the quantification of MiRNA in grapevines under salinity, drought and cold stress. Reference genes are used as internal control in qRT-PCR and are very important because these genes vary in behavior under these abiotic stresses (Akdogan et al., 2016; Yang et al., 2016). The identification of the most suitable and stable reference genes in MiRNA of grapevines for qRT-PCR is very necessary. The fifteen candidate reference genes are studied in grapes for their stability under salinity, drought and cold stress. These fifteen genes include 4 traditional housekeeping genes, Actin (ACT, GenBank Accession: EC969944), Ubiquitin (UBQ, GenBank Accession: EC929411), Glyceraldehyde 3-phosphate dehydrogenase (GAPDH, GenBank Accession: AT1G13440.1), and Elongation factor1-alpha (EF1, GenBank Accession: AT5G60390.1), 9 miRNAs (miR156a, 159a, 160e, 162, 164a, 167a, 168, 169a, and 396a), and 2 non-coding reference genes, 5.8S rRNA (GenBank Accession: KT344661.1) and U6 snRNA (Location: chr6_15577690_15577792_+). The lowest value of CV (coefficient of variance) and SD (standard deviation) are considered as evaluation criteria for the stability of reference genes under these three stresses. Among these fifteen reference genes miR156, miR159a, miR162, miR167a, miR169a and miR396a are excluded from further studies because of their instability under salinity, cold and drought stress. The gene 5.8S rRNA is highly expressive under salinity and drought stress while GADPH shows highest level of expression under drought stress (Luo et al., 2018).

When the remaining nine genes are checked for their behavior under salinity during experiment, the results show that the gene U6 snRNA and miR164a are ranked at top three in all logarithms for their stability and shows least structural variations under stress. While the gene 5.8S rRNA and UBQ show maximum structural variations due to salt stress and are least stable. While the structural variations of all other genes are given in Table 1:

Table 1: Candidate reference genes in grapevines under salinity stress

Rank	**geNorm**		**NormFinder**		**deltaCt**		**Bestkeeper**	
	Gene	SV	Gene	SV	Gene	SV	Gene	SV
1	miR160e	0.212	U6 snRNA	0.010	U6 snRNA	0.605	U6 snRNA	0.201
2	miR164a	0.212	miR164a	0.010	miR164a	0.611	miR164a	0.256
3	U6 snRNA	0.217	EF1	0.016	miR160e	0.667	miR168	0.230
4	UBQ	0.625	UBQ	0.034	UBQ	0.852	UBQ	0.411
5	5.8S rRNA	0.781	5.8S rRNA	0.060	5.8S rRNA	1.374	5.8S rRNA	1.150

Under drought stress, miR168 and UBQ are the most stable reference genes while miR164a, GAPDH and U6 snRNA shows minimum stability in grapevines as in table 2:

Table 2: Candidate reference genes in grapevines under drought stress

Rank	geNorm		NormFinder		deltaCt		Bestkeeper	
	Gene	SV	Gene	SV	Gene	SV	Gene	SV
1	UBQ	0.255	miR168	0.024	miR168	1.130	miR168	0.484
2	miR168	0.765	UBQ	0.036	UBQ	1.139	miR164a	0.645
3	GAPDH	0.789	miR164a	0.040	GAPDH	1.410	miR160e	0.680
4	miR164a	1.164	GAPDH	0.051	miR164a	1.427	UBQ	0.934
5	U6 snRNA	1.271	U6 snRNA	0.057	U6 snRNA	1.584	GAPDH	1.320

Under cold stress, U6 snRNA, miR168 and miR160e are the reference genes among these Nine that show maximum stability expression while miR164a and UBQ are the least stable in grapevines as shown in table 3:

Table 3: Candidate reference genes in grapevines under cold stress

Rank	geNorm		NormFinder		deltaCt		Bestkeeper	
	Gene	SV	Gene	SV	Gene	SV	Gene	SV
1	miR160e	0.248	U6 snRNA	0.009	U6 snRNA	1.069	U6 snRNA	0.108
2	miR168	0.248	miR160e	0.019	miR168	1.167	miR168	0.249
3	U6 snRNA	0.363	miR168	0.022	miR160e	1.207	miR160e	0.448
4	miR164a	1.154	miR164a	0.078	miR164a	2.124	miR164a	1.215
5	UBQ	1.515	UBQ	0.093	UBQ	2.786	UBQ	2.436

5. Conclusion:

This review provides a detailed overview of the behavior of grapevines under abiotic stresses and briefs the interaction of plants with these abiotic stresses. Grapevines have very slow rate of natural adaptations for their survival under changing climatic conditions. The overview of the modern research for the management of heat stress and hormonal imbalance in grapevines through kaolin application provides an understanding to stabilize the plant structure and sustain the fruit yield. It also coves the details of genes expression under salinity, drought and cold stress and the identification of the most stable reference genes for MiRNA qRT-PCR in grapevines for the tolerance. However, further study is need for the identification of the effects of other useful chemicals and genes for the development of resistance and transgenic plants for the tolerance to these abiotic stresses.

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