Photosynthesis limiting stresses under climate change scenarios and role of chlorophyll fluorescence: A review article

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Abstract: Continuous agricultural and other activities of human being have caused changes in the chemistry of global climate, as a consequence many biotic and abiotic stresses that reduce photosynthetic capacity of plants have emerged. Therefore, the aim of this review is to review photosynthesis limiting stresses under climate change scenarios and role of chlorophyll fluorescence on this stress. Different research findings indicate that UV-B radiation cause changes in biological processes of plants such as damage to the internal structure of photosynthesis or control its cellular process. Other type of stress is drought stress, which inhibits photosynthetic electron transport through Photosystem II and damages the oxygen evolving complex of PSII. On the other way, high night temperature stresses are increasing, and it can cause constant suppression of net CO₂ assimilation rate in both C3 and C4 plants. Photoinhibition is considered as reactive oxygen species induced reduction of the primary acceptor of PSII plastoquinone (QA) or change in recombination between acceptor and donor side of PSII. For assessing the effect of stress on photosynthesis, chlorophyll fluorescence is mostly used parameter and also it is an effective indicator of photosynthesis limiting stress and their mechanisms.

Subjects: Agriculture & Environmental Sciences; Plant Biology; Plant Ecology;

Keywords: Photosynthesis; UV-B; photoinhibition; night temperature; drought; chlorophyll fluorescence

1. Introduction
Global climate is the result of a complex interplay of various atmospheric conditions and their interaction. Agricultural and other activities of human being have caused changes in the chemistry of the climate, as a consequence many biotic and abiotic stress that reduce photosynthetic...
capacity of plants have occurred (Houghton et al., 2001; Reicosky et al., 2000). Photosynthesis is a complex process of redox reaction that occurs when the light harvesting complex absorbs photonic energy and transfers it to photosystem reaction centers (Baker, 2008). However, stresses such as UV-B, drought, high temperature, and high light (photoinhibition) can cause a reduction of the electron transport chain (ETC), which leads to photooxidation of photosystem II (C.H. Foyer et al., 2012; Kangasjarvi et al., 2012; Rochaix, 2011). Due to increased industrialization and resulting chlorofluorocarbon release in to the atmosphere the earth’s protective stratospheric ozone layer has been depleted (Dentener et al., 2001).

Nowadays, continued depletion of the ozone layer is main concern because this layer absorbs the harmful Ultraviolet-B radiation (280–320 nm), and it avoids its damage on plant photosynthetic process. However, collapse of ozone molecule within the stratosphere currently reduce UV-B absorption by stratospheric ozone layer and that result high UV-B absorption by our planet earth, when stratospheric ozone layer reduced by 1% UV-B radiation reaching in to the earth surface increase by 31.8% (M. M. Caldwell & Flint, 1994; McKenzie et al., 2003). This high UV-B radiation mainly affect plant photosynthesis (Lidon, 2012; Lidon & Ramalho, 2011; Lidon et al., 2012).

Nowadays, drought is one of most known factor that inhibits crop photosynthesis, and its one of the most causes of crop loss throughout the world, reducing yields of main crop plants by 50% (Bray et al., 2000; Wang et al., 2003). This yield reduction was due to drought stress effects on plant photosynthesis, since lack of water damage basic organizational structures of photosynthesis and in turn inhibit carbon assimilation (Ali & Ashraf, 2011; Golldack et al., 2011), the main reason for low carbon assimilation was due to stomatal limitation by drought stress (Degl’Innocenti et al., 2009; Misson et al., 2010).

As climate is continued changing worldwide temperature is estimated to continuously increase. According to (IPCC, 2014) report global mean temperature has increased by 0.8°C in the 20th century and it is predicted to increase by 3–5°C in 21st century. Photosynthesis is the most sensitive to high temperature stress (Sharkey & Schrader, 2006). High temperature affects photosynthesis by causing reduction of the oxidation property of PSII acceptors and diminishes the efficiency of photosynthetic electron transport of both photosystem PSII and photosystem PSI (Mathur et al., 2014). However, night temperatures are increasing as a result of climate change and it damage thylakoid membrane (Ristic & Prasad, 2007). Also, high night temperature reduce photosystem II quantum yield (Yang et al., 2002; Pradhan et al., 2012), and this result reduction in total photosynthetic efficiency of crop plants (Prasad et al., 2008).

The other types of stress are photoinhibition which is defined as light-induced inhibition of photosystem II activity (Murata et al., 2007). However, the extent of photoinhibition depends on the balance between photo damage and repair capacities of PSII (Demmig-Adams et al., 2012).

Normally, chlorophyll fluorescence is used to study over all photosynthetic process in plants (Murchie & Lawson, 2013), because it is user friendly and non-invasive. Many researches are done on chlorophyll fluorescence and its role to supply information’s related to photosynthetic process of plants (Guo & Tan, 2015; Kalaji et al., 2017; Ruban, 2016; Stirbet et al., 2018). Therefore, the aim of this review is to assess photosynthesis limiting stresses under climate change scenarios and role of chlorophyll fluorescence on this stress.

2. Photosynthesis limiting stresses

2.1. Increasing Ultraviolet-B radiation

Ultraviolet-B radiation was studied by two methods such as attenuation and exclusion study as shown in (Figure 1). Ultraviolet-B radiation (280–320 nm) quantity in the solar spectrum was very small but it affects plants at molecular, cellular, and organism level (M. M. Caldwell et al., 2007; Jenkins, 2009). Actually, UV-B radiation is absorbed by large molecules such as nucleic acids,
proteins, and lipids. Therefore, it can cause change in biological process of plants by damaging internal structure of photosynthesis or controlling their cellular process (Jenkins, 2009; Tian & Yu, 2009).

UV-B radiation effect on internal structure of photosynthesis was altering general photosynthetic process (Reddy et al., 2003), water metabolism (Fuhrer & Booker, 2003), partitioning the carbon from growth pools to secondary metabolic pathways (Bassman, 2004), and its effect observed externally in plants, such as tissue chlorosis and necrosis, change in leaf ultrastructure and anatomy (Jenkins, 2009; Lidon & Ramalho, 2011; Tevini, 2004). Also, several studies showed reduction of stomatal conductance in response to UV-B radiation (Lidon & Ramalho, 2011), and the reduction of stomatal conductance result in CO₂ limitation in many crops (Lidon & Ramalho, 2011; Pal et al., 1999), and the reduction of stomatal conductance result because of its damage at both biochemical and biophysical level (Lidon & Ramalho, 2011). On the other hand, UV-B affect ribulose-1,5-bisphosphate carboxylase/oxygenase content and activities (Correia et al., 1999; Savitch et al., 2001), also, the RuBP regeneration capacities (Allen et al., 1997; Savitch et al., 2001). This effect was because of changes in proteins by photooxidation, reactive oxygen species and free radicals produced by UV-B radiation (C. R. Caldwell, 1993; Foyer et al., 1994). However, UV-B radiation mainly affects the chloroplast that leads to weakening of the photosynthetic function (Allen et al., 1998; Lidon et al., 2012), and also it may totally suppress chlorophyll synthesis(Kulandaivelu et al., 1991). As shown in (Figure 2) UV-B radiation was high at...
highland area and the pigment anthocyanin increase as a mechanism of plants to protect the damage caused by UV-B radiation.

Many studies showed that photophosphorylation process is most sensitive part from thylakoid membrane on exposure to UV-B radiation (Bolink et al., 2001; correia et al., 1999; Lidon et al., 2012; Savitch et al., 2001). On PSII, UV-B radiation function as either the reaction center or producing dissipative sinks for excitation energy (Lidon & Ramalho, 2011). The water oxidizing complex seems to be UV-B sensitive (Lidon et al., 2012), since, the Mn cluster of water oxidation was the most easily broken part of the electron transport chain, UV-B absorption by the protein matrix may cause conformational changes and can cause inactivation of the Mn cluster.

2.2. Increasing drought stress
Drought affects photosynthesis by reducing carbon and nitrogen assimilation capacities, as a result of stomatal and non-stomatal effects of drought, because plants respond to drought by a rapid closure of stomata (Mwanamwenge et al., 1999; Yordanov et al., 2000, 2003). Many studies indicate that photosynthetic rate decline under drought stress was due to low CO₂ concentration at the acceptor site of ribulose-1,5 bisphosphate carboxylase/oxygenase (Bunce, 2009; Lawlor & Tezara, 2009)), or hold back of photosynthetic enzyme synthesis mainly rubisco (HauptHerting & Fock, 2000), also, ATP synthesizing ability (Nogués & Baker, 2000; Tezara et al., 1999). Moreover, drought stress inhibits photosynthetic electron transport through PSII and damages the oxygen evolving complex of PSII (Lu & Zhang, 1999; Skotnica et al., 2000), and as a result of drought vegetative growth become low as shown (Figure 3).

Drought reduce vegetative growth due to its effect of photosynthetic pigment reduction, since drought reduces total chlorophyll content and the reduction was attributed to ultrastructural deformation of plastids, which in turn causes unraveling of PSII that captures photons (Yang et al., 2001), and causing reduction of its efficiency in electron transfer (Kannan & Kulandaivelu, 2011). This decline was due to stress-induced destruction of pigment forming biosynthetic pathways or its degradation. The decrease in chlorophyll content is generally observed fact under drought stress condition (Bijanzadeh & Emam, 2010; Din et al., 2011).

Many findings indicate that drought first cause stomatal limitation, then change photosynthetic reaction mechanism's (Flexas et al., 2008; Zlatev & Yordanov, 2004). Such changes are gas exchange mechanisms, carboxylation efficiency and increase in CO₂ compensation point that result in fluctuations of CO₂ carves of photosynthesis (Zlatev & Yordanov, 2004). Drought
showed a reduction in both the initial slope of those curves (Zlatev & Yordanov, 2004), at the initial time CO₂ curve and carboxylation efficiency of Rubisco was at its maximal and rate of photosynthesis increase. These indicate the potential of the leaves to restore RuBP, since drought stress led reduction of both Rubisco carboxylation efficiency and RuBP regeneration capacity. However, Photosynthesis mainly based on a balance between Rubisco carboxylation capacity, RuBP utilization and its regeneration (Baker et al., 1997; Nogués & Baker, 2000). On the other hand, drought hinder biochemical processes of photosynthesis by changing ionic or osmotic conditions, which reduce ATP syntheses (HauptHerting & Fock, 2000; Tezara et al., 1999). According to the conclusions of (Liu et al., 2006; Zlatev, 2009) photosynthesis is reduced under drought stress condition because of its effect on biochemical processes related to the PSII reaction, and the associated disconnection of non-cyclic photophosphorylation (Yordanov et al., 2000). This disconnection affects a balance between generation and utilization of electrons, resulting in reduction of electron transport rate. This reduction could be due to a dehydration effect on rubisco that reflect an increase in rubisco hydrolysis, since the amount and activities of rubisco manly determine photosynthesis (Lawlor, 2002).

2.3. High night temperature stress
Scientists reported that night temperature increased by 1.13°C from 1979 to 2003 in Philippines (Peng et al., 2004). Global air circulation model predicts 1.4–5.8°C rise in temperature globally because of expected increase in concentrations of greenhouse gases by the end of the 21st century (IPCC, 2007). Much of this increase in temperature is due to an increase in night temperature. Because of increased cloudiness and less radiant heat loss, night temperatures are expected to increase at a faster rate than day temperatures (Alward et al., 1999). Also, (Dai et al., 2001) reported that many climate models predict significant increase of night temperature compared with day temperature, which narrows the diurnal temperature range.

High night temperature reduce crop production by limiting photosynthetic efficiency (Loka & Oosterhuis, 2010; Turnbull et al., 2002), and increasing respiration rate (Mohammed & Tarpley, 2009). However, (Turnbull et al., 2002) indicated that photosynthesis and respiration respond independently to night temperature but related by their effect on leaf carbon status. High night temperature consistently suppress net CO₂ assimilation rate of both C3 and C4 plants (Bange & Milroy, 2004; Sao et al., 2013; Zhang et al., 2010). Also, it affects photosynthesis by causing leaf chlorophyll damage (Prasad & Djanaguiraman, 2011). (Ristic & Prasad, 2007) reported that high night temperature damage the thylakoid membrane, which result to chlorophyll loss and
decrease the efficiency of photosystem II (PSII) (Pradhan et al., 2012; Yang et al., 2002), and totally reduce crop photosynthesis (Prasad et al., 2008). According to (Figure 4) high night temperature reduce chlorophyll content, photosynthesis rate and increase thylakoid membrane damage.

At the cellular level, high night temperature cause a decrease in antioxidant activity and lead to an increase of reactive oxygen species and its oxidative damage mainly lipid peroxidation and membrane damage (Sairam et al., 2000). Increased reactive oxygen species concentration at high night temperature was a result of decreased antioxidant activity (Djanaguiraman et al., 2010; Prochazkova et al., 2001). This reactive oxygen species cause blockage of PSII reaction center and electron flow, and all these changes lead to reduction of photosynthesis (Djanaguiraman et al., 2010). According to (Schrader et al., 2004) permeability of thylakoid membrane increase under high night temperature, which leads to proton leakage, in turn cause reduction of adenosine triphosphate (ATP) and nicotinamide adenine dinucleotide phosphate hydrogen (NADPH) synthesis, and end up with reduction of photosynthesis.

2.4. Photoinhibition of photosystem II

The inhibition of PSII activity under continuous exposure to high Light is commonly known as photoinhibition (Murata et al., 2007). According to (Murata et al., 2007; Takahashi & Badger, 2011) the primary sources of PSII photodamage is the light-dependent distraction of oxygen-evolving complex (OEC), and which result the release of manganese ions. When LHCII absorbs high light than it used up in photochemistry, photoinhibition surges exponentially that cause severe impairment to PSII (Nishiyama & Murata, 2014; Tikkanen & Aro, 2014). Besides, (Nishiyama & Murata, 2014) reported that superoxide anion radical or singlet oxygen is produced when more electrons are released in the electron transport chain (ETC) than used by the Calvin cycle. Findings of (Allakhverdiev et al., 2004; Allakhverdiev & Murata, 2004; Ohnishi & Murata, 2006) indicate that PSII photoinhibition, ROS, such as superoxide radicals and singlet oxygen produced as a result of high light (photoinhibition).

Studies done by (Murata et al., 2012) give another analysis of the photoinhibition mechanism, he reported that reactive oxygen species do not damage PSII reaction centers directly but inhibit the repair of PSII by inhibiting protein synthesis. The same findings indicate that photodamage to PSII happens by two successive steps: (1) the light dependent destruction of the Mn cluster of the oxygen evolving complex, and (2) the inactivation of the PSII reaction centers by the light that has been absorbed by chlorophyll (Ohnishi et al., 2005). However, (Cazzaniga et al., 2013) indicated that under high photoinhibition non-photochemical quenching (NPQ) act as photoprotector by causing reduction in concentration of chlorophyll excited states (Chl*) in PSII and activate a heat dissipation channel. Moreover, nonphotochemical quenching (NPQ) initiation during photoinhibition was as a result of alterations in the distribution and molecular direction of chlorophyll proteins in the thylakoid membrane (Herbstova et al., 2012; Johnson et al., 2011).

Hypothesis on the impact of stresses other than light on PSII activity indicate that stresses increase the rate of photoinhibition of PSII (Adir et al., 2003; Melis, 1999). Nowadays, this hypothesis has been disproved many researchers showed that the repair mechanism of PSII is more sensitive to other stresses than the process of photodamage itself (Kangasjarvi et al., 2012; Nishiyama & Murata, 2014). Photosystem II is the most sensitive component to photoinhibition in the thylakoid membrane. Therefore, the principal result of other stress is to cause PSII prone to photoinhibition (Nishiyama et al., 2001). However, unlike to PSII, PSI is not regularly damaged by photoinhibition, due to its very efficient mechanism of protecting from photoinhibition (Sonoike, 2011; Tikkanen & Aro, 2014).
3. Role of chlorophyll fluorescence on photosynthesis limiting stresses

3.1. Chlorophyll fluorescence and PSII photochemistry

Chlorophyll a fluorescence is induced when a photosynthetic sample is moved from darkness to high light intensity (Papageorgiou et al., 2007). It is divided into two phases: (1st), the fast induction phase or the OJIP phase, where O is origin, P is peak and J-I are the intermediate phases and (2nd), the slow induction phase, where, P is peak, S is steady, M maximum, and T is the terminal. The high-speed induction kinetics expresses the primary photochemistry of PSII. However, the slow kinetics is a complex phase primarily associated to the interactions with processes in the thylakoids membrane, and reductive carbon cycle of the stroma (Krause & Weis, 1991). In other way, the slow induction phase is emitted from photosynthetic samples in the red infrared region for a short time after the fast fluorescence has decay. The fast phase of the transient gives important information about reduction of electron acceptors during electron transport chain (ETC). On the other hand, it is difficult to interpret the slow transient phase, because a number of different processes such as NPQ, ATP synthesis, and the Calvin cycle are involved on this phase (Stirbet & Govindjee, 2011). However, the slow fluorescence emission of PSII is thought as good approach to study light-induced electron transfer, since electron movement is not visible by conventional spectroscopic (Goltsev et al., 2009). Many researchers have analyzed the slow fluorescence methods to evaluate plant performance under stressful environment (Zhang et al., 2007; Valikhanov et al., 2002).

According to (Zhang et al., 2007) PSII efficiency under normal and stress conditions can be determined by fast chlorophyll a transient (Baker, 2008; Gururani et al., 2013, 2015).

Analysis of fast chlorophyll a transients has a potential give us fascinating facts pertaining to the change and modification of the photosynthetic machinery at different stress conditions. Measuring changes of fast chlorophyll a fluorescence transients become a widely used technique for assessing different stresses. An increase of fluorescence from F0 (minimum) to Fm (maximum) in dark adapted plants exposed to a strong saturating light pulse (3000–12,000 mmol photons m\(^{-2}\) s\(^{-1}\), 200–1000 ms), and at high resolution of (0–200 ms) is known as apolyphasic OJIP transient, it has three phases: OJ (0–3 ms), JI (3–30 ms), and IP (30–200 ms). Latest findings indicate that the increase of fluorescence minimum (F0) and maximum (Fm) show the reduction in the amount of quinine (QA), the 1st electron acceptor of PSII (Schansker et al., 2014). The OJIP or JIP test studied by (Strasser et al., 2004) is the main descriptive model used to explain OJIP transients (Baker, 2008; Baker & Rosenqvist, 2004). The model works by comparing the photosynthetic activities of stressed and normally growing plants it is noninvasive tool for analyzing the effects of different stresses on photosystem II and photosynthetic efficiency (Goltsev et al., 2012; Ranjan et al., 2014). Generally, chlorophyll a fluorescence transients provide very important information about PSII photochemistry and electron transport chain (ETC), and the acceptance of this analytical method on plant photosynthetic research was increasing (Stirbet & Govindjee, 2011).

3.2. Chlorophyll fluorescence on high night temperature stress

High night temperature stress reduces both the ratio of acceptors such as plastoquinone (QA) to reaction centers (RC) and the ratio of reduced acceptors plastoquinone (QB) to (QA). Also, maximum quantum yield of PSII decrease and minimal fluorescence value increase (Brestic & Zivcak, 2013; Chen et al., 2009). However, high night temperature stress also influences the shape of the O–J–I–P curve, decreasing (Fm) and increasing (Fo). The increase in (Fo) may be due to the release of LHC II from the PSII complex, inactivation of PSII photochemical reaction, an inhibition of electron flow or reduction of electron transfer from QA to QB (Mathur et al., 2011), and the decrease in (Fm) was due to denaturation of chlorophyll proteins (Yeman et al., 1997). Also, (Figure 5) indicate that high night temperature reduce photochemical quenching, increase non-photochemical quenching, decrease PSII quantum yield and electron transport rate.
The K peak at 300 s is a well-known symptoms of high night temperature stress, and it is used to indicate the separation of the oxygen evolving complex (OEC) and electron movement between pheophytin and primary electron acceptor (QA) (Laza’r, 2006; Strasser et al., 2000). The direct cause of the chlorophyll florescence curve peak (K) is the discharge of electrons from P680 to PSII acceptors, which over compensates the invasion of electrons from the donor side of PSII to P680, and an increase in the FK/FJ ratio (Srivastava & Strasser, 1995). This process indicates that the high night temperature stress is inhibiting the donation of electrons by the oxygen evolving complex (OEC). Since, the PSII complex performs splitting of water molecules and releasing molecular oxygen through an oxygen evolving complex (OEC) (Gururani et al., 2012; Tikkanen & Aro, 2014), and the released electrons are then transported to the PSI complex via electron transport chain (ETC) from plastocyanin to ferredoxin (Nelloepalli et al., 2014).

3.3. Chlorophyll fluorescence on drought stress
Among the photosynthetic component, PSII is highly resistant to drought compared to PSI and it is affected by drought only at extreme drought conditions (Lauriano et al., 2006). Chlorophyll fluorescence protects PSII and PSI from drought stress by regulating the energy distribution between photosystems and activating alternative electron sinks (Zivcak et al., 2013). It enhances the resistance of PSII to drought stress by causing vanishing of the K band from the OJIP transient (Oukarroum et al., 2012). However, the fluorescence increase during the primary 2–3 s is said to primary photochemistry and it is has been proposed that stimulated L and K bands are often used as a tools to evaluate potential to avoid drought stress (Oukarroum et al., 2007). The L band affects the excitation energy transfer within PSII units, commonly known as connectivity or grouping (Strasser & Stirbet, 1998). The K band has been related to a dissociation of the oxygen evolving complex (Guise et al., 1995).

The measurement of OLJKP fluorescence transients and their analysis using the JIP test could be used as indicators for drought stress tolerance and physiological stability. However, the most generally used parameter from the chlorophyll fluorescence OJIP transient is the performance index (PI), which provides quantitative information about the overall state of plants and their vigor. Performance index (PI) is the product of three independent characteristics: (1) the concentration of reaction centers per chlorophyll, (2) a parameter regarding primary photochemistry and (3) a parameter regarding electron transport (Strasser et al., 2004). Performance index (PI) is sensitive...
to changes in antenna properties, trapping efficiency or electron transport beyond QA. For example, the PI of wheat decline if prolonged drought stress occur after post anthesis. Besides, the drought tolerance of wheat genotypes expected from PI values recorded in drought stress also correlated with the drought tolerance (Zivcak et al., 2008). The most drought tolerant and sensitive races of barley and great millet from Egypt were identified using the PI and chlorophyll fluorescence fast induction curve (Jedmowski et al., 2013). These studies show that drought tolerant and drought sensitive cultivars are often differentiated at the extent of PSII, as shown in (Table 1).

3.4 Chlorophyll fluorescence on UV-B and photoinhibitory stress

The first important indicator derived from Kautsky curve was Fv/Fm ratio (Krause, 1988), and it is a good indicator of the PSII photoinhibition by UV-B and other stresses (Krause & Weis, 1991). The ratio of Fv/Fm ([Fm-Fo]/Fm) indicate maximal photochemical efficiency of PSII and also it indicate functional loss of PSII reaction center's (Öquist et al., 1992). Fv/Fm values are between 0.75 and 0.85, and it is related to quantum yield of photochemistry. If this ratio decline it is considered as photoinhibition and UV-B stress occurred, it is as a result of two different processes (Öquist et al., 1992). 1st PSII Photochemistry rate constant decrease due to damage of photochemistry reaction Centre and an increase in the rate constant of non radiative dissipation of excitation energy. This decrement of PSII photochemistry cause a n increase in initial fluorescence at open PSII (Fo), and maximum fluorescence at closed PSII (Fm) (Kitajim and Butler, 1975). However, the decrease in Fv/Fm ratio is not related to the amount of deactivated PSII reaction centers (Park et al., 1996).

Certainly, Fv/Fm ratio is considered as an indicator of PSII photoinactivation but this ratio decrement was not due to the closure of PSII reaction centers alone but also other processes participate with charge separation mainly thermal dissipation of absorbed light (Malnoë, 2018). Chlorophyll fluorescence quenching analysis has given an advance in the detection of PS II photoinhibition (Bolhär-Nordenkamp et al., 1993). Quenching analysis separate both photochemical and nonphotochemical processes in the quenching of variable fluorescence, by inducing a short closure of all PSII reaction Centre's by saturating light pulse (Baker, 2008; Schreiber et al., 1995).

The low amount of fluorescence due to photochemistry and the charge separation is called photochemical quenching. However, concerning photochemistry the most useful parameters derived from quenching analysis is efficiency of PSII (Genty et al., 1989). Informally, similar to PSII another parameter obtained from quenching

Analysis is coefficient of photochemical quenching, qP, that shows the proportion of open PSII reaction centers (Maxwell & Johnson, 2000). On the other hand, PSII provides information on the electron transport rate and, unlike to Fv/Fm ratio it can determine dark adapted conditions of photoinhibition. However, PSII decline as a result of inactivation of PSII reaction centers due to photoprotection (Krause et al., 1990), or may be a mechanism that adjusts the efficiency of PSII to photosynthetic photon flux density (Critchley, 1994), but at high light condition PSII also decline based on the activity of energy consuming biochemical reactions of CO₂ assimilation (Genty et al., 1989). Besides, the proportion of light energy diverted to photochemistry quenching analysis controls the amount of light energy dissipated by other mechanisms such as non-photochemical quenching (Logan et al., 2014). Similarly, quenching analysis helps to identify the non-photochemical quenching (NPQ), that signifies rapid process and reversible thermal dissipation of absorbed light energy in the PSII antenna (Horton & Ruban, 2005; Ruban et al., 2012).

Non-photochemical quenching (NPQ) is a dissipation mechanism in to heat and many components are involved such as the energy dependent (qE), zeaxanthin-dependent (qZ) and photoinhibitory quenching (qI) (Derks et al., 2015). However, qE and qZ are essential for photoprotection but qI represent the photoinhibitory damage to PSII reaction centres (Ruban et al., 2012), but qE is most effective part at photo protecting PSII reaction centers from damage (Nilkens et al., 2010). In surplus light conditions, a transthylakoidal proton gradient (1pH) is generated, activating qE (Noctor et al., 1993). That can cause acidification of thylakoid lumen and it result in protonation
Table 1. Chlorophyll fluorescence in leaves of control and drought stressed bean plants

| Genotype     | Variant          | F0       | Fm       | Fv/Fm  | Y       | qP       | qN       |
|--------------|------------------|----------|----------|--------|---------|----------|----------|
| Control      |                  |          |          |        |         |          |          |
| Plovdiv      | Primary leaf     | 425 ± 16 | 2083 ± 82| 0.796 ± 0.028 | 0.485 ± 0.021 | 0.773 ± 0.031 | 0.573 ± 0.028 |
|              | I trifoliate leaf| 361 ± 13 | 1900 ± 77| 0.810 ± 0.031 | 0.514 ± 0.026 | 0.811 ± 0.039 | 0.569 ± 0.027 |
| Dobrudjanski| Primary leaf     | 484 ± 19 | 2343 ± 79| 0.793 ± 0.026 | 0.424 ± 0.020 | 0.742 ± 0.032 | 0.644 ± 0.034 |
| Ran          | I trifoliate leaf| 385 ± 13 | 2047 ± 70| 0.812 ± 0.033 | 0.497 ± 0.023 | 0.801 ± 0.041 | 0.681 ± 0.036 |
| Prelom       | Primary leaf     | 407 ± 18 | 2157 ± 74| 0.811 ± 0.035 | 0.491 ± 0.028 | 0.788 ± 0.035 | 0.572 ± 0.032 |
|              | I trifoliate leaf| 382 ± 13 | 1900 ± 66| 0.799 ± 0.029 | 0.534 ± 0.031 | 0.816 ± 0.043 | 0.546 ± 0.027 |
| Plovdiv 10   | Primary leaf     | 484 ± 19 *| 1820 ± 64| 0.734 ± 0.025 | 0.262 ± 0.013 ***| 0.495 ± 0.026 ***| 0.802 ± 0.042 ***|
|              | I trifoliate leaf| 398 ± 15 | 1780 ± 74| 0.776 ± 0.027 | 0.324 ± 0.017 ***| 0.584 ± 0.037 ** | 0.745 ± 0.038 **|
| Drought problem|                  |          |          |        |         |          |          |
| Dobrudjanski| Primary leaf     | 570 ± 24 *| 1915 ± 71 *| 0.702 ± 0.021 *| 0.107 ± 0.011 ***| 0.356 ± 0.022 ***| 0.969 ± 0.051 ***|
| Ran          | I trifoliate leaf| 433 ± 15 *| 1721 ± 58 *| 0.748 ± 0.024 | 0.204 ± 0.014 ***| 0.457 ± 0.028 ***| 0.984 ± 0.053 ***|
| Prelom       | Primary leaf     | 451 ± 19 | 1914 ± 68 *| 0.765 ± 0.023 | 0.397 ± 0.019 *| 0.559 ± 0.036 ** | 0.670 ± 0.041 |
|              | I trifoliate leaf| 403 ± 14 | 1850 ± 67 | 0.782 ± 0.028 | 0.465 ± 0.024 * | 0.668 ± 0.039 *   | 0.607 ± 0.033 |

Source: (Zlatev & Yordanov, 2004)
of PSII subunits protein, then activates Violaxanthine-oxidase, which in turn changes violaxanthin (Vio) in to zeaxanthin (Zea) (Demming-Adams, 1990). Both protonation of PSII subunits protein (Psbs) and (Zea) cause an increase in the sensitivity of LHClI to the lumen protons inducing qE (Horton et al., 2000; Ruban et al., 2012). qZ coefficient is formed within 10–30 min, and it is independent to psbs and1pH, even strictly dependent to Zeaepoxidation and encourages conformational change of minor antenna protein CP26. However, qE and qZ changes the LHClI (Dall’Osto et al., ; Nilkens et al., 2010).

The final quenching coefficient qL is relatively slower to relax and losses its number of active PSII reaction centers at time of photoinhibition (Derks et al., 2015). However, this independent portion named as qH (Malnoé et al., 2017), that includes different processes. Some are photoprotecting antenna and has similar mechanisms with qE and qZ. These mechanisms act in a different way to dissipate the excess excitation energy (Malnoé et al., 2017). The qH coefficient gives information on the decline of Fv/Fm ratio and it can result a high Fo due to inactivation of PSI reaction centers or antenna detachment, also both Fo and Fm decline if qH is present.

4. Conclusion
Our world is rapidly becoming industrialized and this result emission of toxic chemical compounds in to the atmosphere that deplete protective stratospheric ozone layer. As a result, Ultraviolet-B radiation absorption by the earth increase, then it reduces photosynthetic capacity of plants by directly damaging photosynthetic structures and process. In addition, other stress such as photoinhibitory, high temperature and drought stresses gets advantage and affects the photosynthetic capacity in integrated way. Nowadays, these stresses are reducing photosynthesis and affecting crop production and productivity in general. Therefore, controlling this photosynthetic limiting stress works must be done on such area: 1. Employing chlorophyll fluorescence to know which part of photosynthetic process is affected by this stress. 2. Breeding must be done by identifying good performing genes by chlorophyll fluorescence.

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