International Multidisciplinary Research Journal 2015, 5: 6-15
http://scienceflora.org/journals/index.php/imrj/

Triazole-induced drought stress amelioration on growth, yield, and pigments composition of *Helianthus annuus* L. (sunflower)

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Received: 07.05.2015
Revised: 16.07.2015
Accepted: 21.07.2015
Published: 23.07.2015

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ABSTRACT

In this investigation, a pot culture experiment was conducted to estimate the ameliorating effect of drought stress and drought with triazole compounds (hexaconazole, propiconazole, and tebuconazole) response on growth analysis, pigment composition, and yield parameters of *Helianthus annuus* L. (Sunflower). Sunflower is one of the most important oil crops and due to its high content of unsaturated fatty acids and a lack of cholesterol, the oil benefits from a desirable quality. Plant growth and productivity are unfavorably affected by nature's wrath in the form of various biotic and abiotic stress factors. Water deficit is one of the major abiotic stresses, which adversely affects crop growth and yield. Drought stress during vegetative phase, flowering or seed filling period causes considerable decreases in yield and oil content of sunflower. These changes are mainly related to altered metabolic functions, one of those is either loss of or reduced synthesis of photosynthetic pigments and biochemical modifications. From 30 days after sowing (DAS), the plants were subjected to 4 days interval drought stress and drought with triazole compounds and daily irrigation kept as a control. The plant samples were collected on 40, 50, and 60 DAS. Growth, yield parameters, and pigment variations were analyzed. Drought stress decreased growth, yield, and pigments composition chlorophyll, carotenoid, and anthocyanin when compared to control. The triazole ameliorated drought stress by increasing the growth and biochemical potentials and bring into being the way for overcoming drought stress in *H. annuus* L. plants.

KEY WORDS: Drought stress, growth parameters, pigments, triazole

INTRODUCTION

Helianthus annuus L. belongs to Compositae family. Sunflower is one of the major and most important non-conventional oilseed crops in the world due to its excellent oil quality. Although sunflower is known as a drought tolerant crop or grown under dry land conditions, substantial yield increases are achieved with frequent irrigation. Water is essential for crop production, and best use of available water must be made for efficient crop production and higher yields. Water deficit affects crop growth, depending on the stage of growth and the degree or intensity of water stress (Clavel *et al.*, 2005). Stress is the altered physiological condition caused by factors that tend to alter equilibrium. The strain is any physical and chemical change produced by stress (Hu *et al.,* 2006). Water stress inhibits cell enlargement more than cell division and reduces plant growth by inhibition of various physiological and biochemical processes such as photosynthesis, respiration, translocation, ion uptake, carbohydrates, nutrient metabolism, and hormones (Bhatt and Rao, 2005).

Triazole compounds have both fungitoxic and plant growth-regulating properties (Jaleel *et al.*, 2006). In addition, they can also protect plants against various environmental stresses (Jaleel *et al.*, 2007; 2008). Triazoles are having antifungal activities (El-Serwy *et al.*, 2013). These were primarily employed to control animal and plant disease caused by pathogenic fungi; several triazole formulations have been found to possess plant growth-regulating properties too (Pan *et al.*, 2013). Plant growth regulators play important roles in plant growth and development (Sivakumar and Panneerselvam, 2011). Triazole compounds, such as triadimefon, paclobutrazol, uniconazole, propiconazole (PCZ), and hexaconazole

(HEX), have growth-regulating properties and induce many morphological and metabolic changes such as reduction in shoot elongation, stimulation of rooting, inhibition of gibberellin biosynthesis, increased chlorophyll content, altered carbohydrate status, and increased abscisic acid and cytokinin synthesis (Kishorekumar *et al.*, 2006 and Jaleel *et al.*, 2007). The aim of present study was to evaluate drought stress triazoles-induced drought tolerance on growth, yield parameters and pigments level of sunflower plants.

MATERIALS AND METHODS

Economically important oilseed crop sunflower (*H. annuus* L.), belonging to the family Astreaceae (Compositae) was selected for the present investigation. The sunflower variety Sunbred – 275 PR (ARENA) was obtained from Syngenta India Limited and used for the present study. Pot culture experiments were conducted to study the growth parameters, biochemical and physiological changes, and antioxidant potential of the crop studied. The experimental seeds were surface sterilized with 0.2% mercuric chloride solution for 5 min with frequent shaking and thoroughly washed with tap water. The experiment was laid out in a completely randomized block design (CRBD).

The triazole compounds, namely HEX, tebuconazole (TBZ), and PCZ, were used in this study and to determine their optimum concentration, each compound was tested with 5, 10, 15, and 20 mg/L concentrations, and among the concentrations tested, 10 mg/L of HEX, 15 mg/L of TBZ, and 15 mg/L of PCZ increased the dry weight of sunflower plants significantly and their higher concentrations slightly decreased the growth and dry weight. In the lower concentrations, there was no significant change in dry weight and growth response of sunflower. Hence, the level of concentration stated above for each triazole was determined as optimum concentration, and they were used in this investigation to study their overall effect on the crop studied.

Plastic pots of 40 cm diameter and 45 cm height were used in this study, and each pot was filled with 10 kg of soil mixture containing red soil, sand, and farm yard manure at 1:1:1 ratio and the pots were arranged in CRBD. One set containing 50 pots was kept as control, and another set of 50 pots was used for drought stress inducement and the remaining three sets of 150 pots were used for drought stress along with triazoles treatment. The sunflower seeds were sown in the pots and the seedlings were thinned to 1 per pot on the 10th day after sowing (DAS). The plants were allowed to grow up to 30 DAS. From 30th to 50th day (before flowering period), all the potted plants were grown under the poly house. The control plants were irrigated on alternative days. Drought stress (irrigation was performed at 4 days interval) and drought stress (4 days interval) with triazoles treatment performed at 10 days interval, i.e., on 30th, 40th, and 50th days. After the treatment period, irrigation was made on alternative days, and it was followed up to harvest period (120-day). Then, the plants were uprooted randomly on 40th, 50th, and 60th DAS washed carefully and separated into root, stem, and leaf for estimating growth parameters, pigments, and yield.

Growth Parameters

Root and shoot length

Root and shoot length were recorded on 40th, 50th, and 60th DAS. Below the point of root stem transition to the tap root and the length of lateral roots were taken as total root length. The length between stem tip and point of root stem transition region was taken as stem length. The root length and the stem length were expressed in centimeters per plant.

Total leaf area

The total leaf area was measured using LICOR Photo Electric Area Meter (Model LI-3100, Lincoln, USA) and expressed in cm^2 per plant.

Whole plant fresh weight and dry weight

After washing the plants in the tap water, fresh weight of plant was determined by using an electronic balance (Model – XK3190-A7M) and the values were expressed in gram. After taking the fresh weight, the plants were dried at 60°C in hot air oven for 24 h. After drying, the weight was measured, and the values were expressed in gram.

Yield parameters

The yield parameters such as a total number of seeds and 100 seeds weight and head diameter were measured at the time of harvesting period.

Estimation of oil content

Oil content was extracted from the sunflower seeds and estimated according to the method of Jayaraman (1981).

Two gram of sunflower cotyledon and ground it in a pestle and mortar with 10 ml of methanol – chloroform mixture (1:2). Reextract the residue twice with 10 ml of methanol – chloroform mixture and pool the extract in a beaker. Add 20 ml of chloroform and sterile it for 5 min then 3 ml of 0.1 M KCL was added and allowed it to settle for 10 min. Filter the extract through three layers of cheesecloth in a pre-weighed 50 ml beaker. Evaporate the organic solvent under hot air for dry and take the final weight of beaker and content. By subtracting the initial weight from the final weight of the beaker, the oil content was found and expressed in mg/g fresh weight.

Photosynthetic Pigments

Chlorophylls and carotenoid content

Chlorophyll and carotenoid contents were extracted from the leaves and estimated according to the method of Arnon (1949). 500 mg of fresh leaf material was ground with 10 ml of 80% acetone at 4°C in a pestle and mortar and centrifuged at 2500 g for 10 min at 4°C. The residue was re-extracted with 80% acetone until the green color disappeared in the residue and the extracts were pooled and transferred to a graduated tube and made up to 20 ml with 80% acetone and assayed immediately.

3 ml of the extract were transferred to a cuvette, and the absorbance was read at 645, 663, and 480 nm in a spectrophotometer (U-2001–Hitachi) against 80% acetone as a blank. Chlorophyll content was calculated using the formula of Arnon (1949).

$$\text{Total chlorophyll (mg/ml)} = (0.0202) \times (A.645) + (0.00802) \times (A.663)$$

$$\text{Chlorophyll "a" (mg/ml)} = (0.0127) \times (A.663) - (0.00269) \times (A.645)$$

$$\text{Chlorophyll "b" (mg/ml)} = (0.0229) \times (A.645) - (0.00468) \times (A.663)$$

Carotenoid content was calculated using the formula of Kirk and Allen (1965) and expressed in milligram per gram fresh weight.

$$\text{Carotenoid} = A.480 + (0.114 \times A.663 - 0.638 \times A.645)$$

Anthocyanin content

Anthocyanin content was extracted and estimated by the method of Zhang and Quantick (1997). In a pestle and mortar, 500 mg of tissue was ground with 10 ml of 1% methanol and repeated three times. The homogenate was centrifuged at 19,000 g for 15 min. The resultant supernatant was diluted with 1% HCl - methanol to 50 ml. The absorption of diluents was measured at 530 nm. The anthocyanin contents were expressed in mg/g fresh weight.

RESULTS AND DISCUSSION

Growth Parameters

Root length

Drought stress increased the root length in sunflower to a larger extent and it was 141.11% over control on 60th DAS. The root length increased in drought stress with triazole treatments when compared to control. The extent of increase in HEX, in TBZ, and in PCZ was 159.21%, 155.07%, and 152.81%, respectively, over control on 60th DAS (Figure 1). The root length increased in drought-stressed sunflower plant when compared to control. Drought stress increased the root length in sunflower (Manivannan *et al.,* 2007), olive (Bacelar *et al.,* 2007), parsley (Petropoulos *et al*., 2008), *Triticum aestivum* (Dickin and Wright, 2009), and in chickpea (Ceylan e*t al*., 2013). The development of root system may increase the water uptake under drought stress. The root length increased in triazoles treatment under drought stress when compared to control. Triazole treatment increased the root growth in rose (Jenks *et al.,* 2001) under drought stress. Triazoles increased the diameter and length of fibrous roots and enhanced the lateral root formation in tomato plants (Mohamadi and Rajaei, 2013).

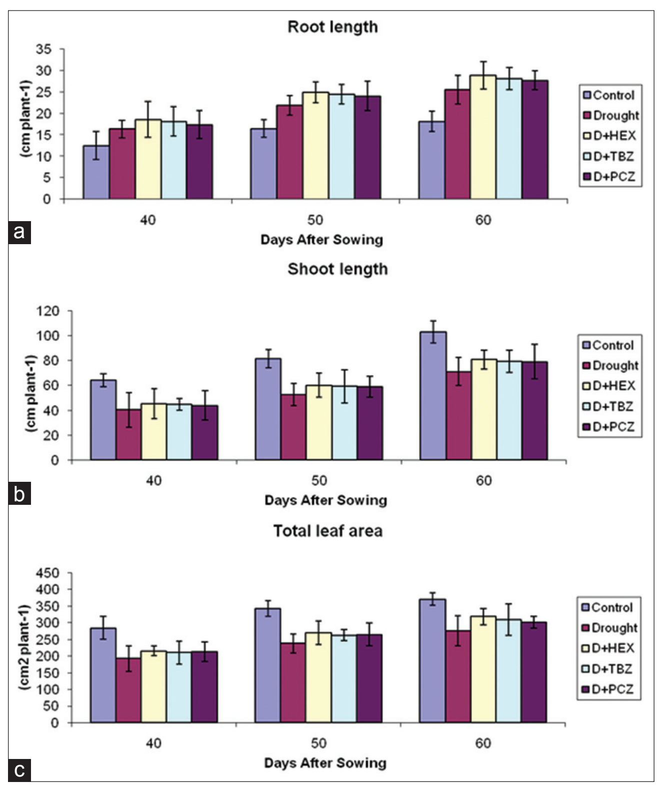

Figure 1: (a-c) Effect of drought stress and drought with triazoles treatment on root, shoot length, and total leaf area of sunflower

Shoot length

The shoot length decreased in drought-stressed plants when compared to control and it was 69.22% over control on 60th DAS. Drought stress with triazoles treatment caused an enhancement in stem length when compared to drought-stressed plants in all sampling days. Triazoles treatment decreased the stem length, and the results were 78.49 in HEX, 77.16 in TBZ, and 76.91% in PCZ over control on 60th DAS (Figures 1 and 2). Drought stress inhibited the shoot growth significantly in sunflower and drought with triazole treatments when compared to control. Similar results were observed in okra (Sankar *et al*., 2007), pearl millet (Kusaka *et al.,* 2005), chickpea (Ceylan *et al*., 2013), and *Petroselinum crispum* (Petropoulos *et al.,* 2008). Decrease in shoot length may prevent excess water loss by reducing the number of active stomata and transpiration rate. Triazole treatment to the drought-stressed plants increased the stem length when compared to drought-stressed plants and decreased when compared to control. Paclobutrazol increased stem length under drought stress in rose plants (Jenks *et al.,* 2001) and triadimefon in *Lycopersicon esculentum* (Mohamadi and Rajaei, 2013).

Total leaf area

Total leaf area reduced under drought stress when compared to control in sunflower and it was 74.45% over control on 60th DAS. Drought stress with triazoles caused an increase in leaf area when compared to drought-stressed plants in all the sampling days, and they were 85.78 in HEX, 83.27 in TBZ, and 81.11% in PCZ over control on 60th DAS (Figure 1). Drought stress reduced the leaf area when compared to control in sunflower.

The leaf growth was more sensitive to water stress in maize (Nayyar and Gupta, 2006). Similar results were observed under drought stress in *Abelmoschus esculentum*

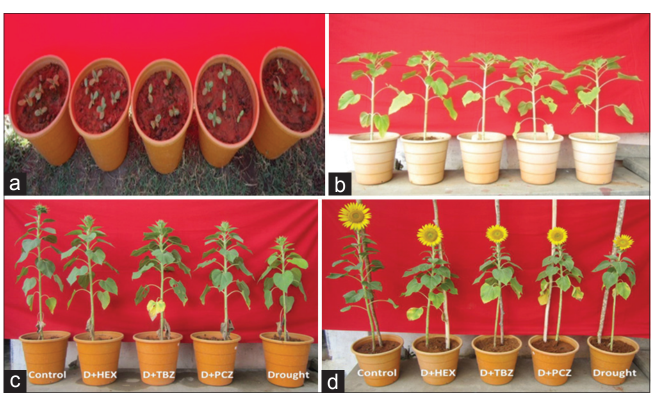

Figure 2: Different growth stages of sunflower plants under drought stress and drought with triazole treatments. (a) 7 days old sunflower seedlings; (b) 30 days old sunflower plants. (c) 40 days old sunflower plants after treatments; (d) 60 days old sunflower plants after treatments

(Bhatt and Rao, 2005), cowpea (Anyia and Herzog, 2004), and olive (Bacelar *et al.,* 2007). Triazole treatment to the drought-stressed plants resulted in increased leaf area in sunflower plants when compared to drought-stressed plants but decreased when compared to control. Triazole treatment increased the leaf area in *L. esculentum* (Mohamadi and Rajaei, 2013) and *Syzygium* (Roseli *et al.,* 2012).

In drought-stressed plants, the shoot length and total leaf area decreased, but root length increased to a larger extent. Triazole treatments to drought-stressed plants increased the root length, stem length, and total leaf area when compared to drought stress. Among the triazole compounds tried HEX had a significant ameliorative effect on drought stress and on morphological parameters studied in sunflower.

Whole plant fresh weight

Drought stress decreased the whole plant fresh weight to a larger extent and it was 65.91% over control in sunflower. The fresh weight increased in drought stress with triazoles treated plants, and they were 76.45 in HEX, 75.68 in TBZ, and 74.69% in PCZ over control (Tables 1 and 2). Drought stress treatment decreased the whole plant fresh weight in sunflower plants. Similar results were observed in pearl millet (Kusaka *et al.,* 2005) and *A. esculentum* (Bhatt and Rao, 2005 and Sankar *et al*., 2007). The reduction in fresh weight under drought condition might be due to suppression of cell expansion and cell growth due to the low turgor pressure and partial root drying caused a significant reduction in shoot biomass when compared to control as observed in wheat (Shao *et al.,* 2005a and b), cowpea (Anyia and Herzog, 2004), and chickpea (Ceylan *et al*., 2013). Triazole treatment to drought-stressed plants increased the fresh weight, but it was lower than that of control. Similar results were reported in *Catharanthus* (Jaleel *et al*., 2007) and triamidefon in *L. esculentum* (Berova *et al.,* 2000; Mohamadi and Rajaei, 2013).

Whole plant dry weight

Drought stress caused decreased dry weight accumulation in sunflower and it was 69.55% over control on 60th DAS. Drought stress with triazole treatments increased the dry weight when compared to drought-stressed plants, and the results were 77.77 in HEX, 76.89 in TBZ, and 75.95% in PCZ over control on 60th DAS (Tables 1 and 2). Drought stress decreased the dry weight in sunflower plants. A decrease in plant biomass was reported in drought-stressed wheat (Shao *et al.,* 2007) and *Asteriscus maritimus* (Rodriguez *et al.,* 2005). Severe water stress arrests photosynthesis, disturbance of metabolism, and finally

Table 1: Effect of drought stress and drought with triazoles treatment on whole plant fresh and dry weight of sunflower (expressed in gram/plant)

DAS	Control	Drought	D+HEX	D+TBZ	D+PCZ
Whole plant fresh weight (expressed in grams/plant)					
40	57.48±5.34	34.63±5.88	37.41±4.99	36.84±5.27	35.95±4.77
50	84.26±5.19	55.41±6.32	59.05±5.56	58.52±4.85	58.04±5.30
60	127.95±6.58	84.34±6.04	97.82±7.08	96.84±6.39	95.57±6.22
Whole plant dry weight (expressed in grams/plant)					
40	14.52±1.77	8.92±1.41	10.07±1.68	10.00±1.21	9.94±1.74
50	19.93±1.18	12.56±1.15	14.62±1.73	14.09±1.66	14.05±1.83
60	28.61±1.27	19.9±1.33	22.25±1.29	22±1.48	21.73±1.25

Values are mean±SE of seven replicates. SE: Standard error, DAS: Days after showing, HEX: Hexaconazole, TBZ: Tebuconazole, PCZ: Propiconazole

Table 2: Effect of drought stress and drought with triazoles treatment on pigment composition of sunflower (expressed in mg/g fresh weight)

DAS	Control	Drought	D+HEX	D+TBZ	D+PCZ
Carotenoid					
40	0.164±0.014	0.075±0.009	0.086±0.012	0.082±0.011	0.084±0.014
50	0.245±0.016	0.128±0.015	0.143±0.018	0.137±0.017	0.135±0.019
60	0.296±0.019	0.173±0.017	0.195±0.014	0.188±0.018	0.19±0.021
Anthocyanin					
40	0.148±0.019	0.08±0.011	0.106±0.013	0.102±0.015	0.98±0.018
50	0.274±0.016	0.165±0.017	0.205±0.014	0.195±0.018	0.19±0.019
60	0.318±0.021	0.207±0.015	0.247±0.018	0.241±0.016	0.238±0.022

Values are mean±SE of seven replicates. SE: Standard error, DAS: Days after showing, HEX: Hexaconazole, TBZ: Tebuconazole, PCZ: Propiconazole

dying (Liang *et al*., 2006). Similar results were observed in wheat (Shao *et al*., 2007) and Liang *A. esculentus* (Sankar *et al*., 2008). A common adverse effect of water stress on crop plants is the reduction in fresh and dry biomass production (Farooq *et al.,* 2009).

Triazole treatment to the drought-stressed sunflower plants increased the whole plant dry weight when compared to drought-stressed plants. Triazole increased the whole plant dry weight in rose (Jenks *et al.,* 2001). Similar results were observed in *L. esculentum* (Still and Pill, 2004; Mohamadi and Rajaei, 2013). The alteration of hormonal status induced by triazole might be the cause for the increased dry weight under drought stress.

Yield parameters - head diameter

In sunflower plants, the drought stress decreased flower head diameter significantly, and it was 64.79% over control on 60th DAS. Drought stress with triazole treatments increased the head diameter when compared to drought-stressed plants, and they were 77.28 in HEX, 74.95 in TBZ, and 72.04% in PCZ over control (Figure 3).

Total number of seeds per head

Drought stress decreased the total number of seeds per head to a larger extent and it was 63.87% over control in sunflower. Drought stress with triazoles increased the total number of seeds per head when compared to drought-stressed plants, and the results were 80.74 in HEX, 75.37 in TBZ, and 74.67% in PCZ over control (Figure 3).

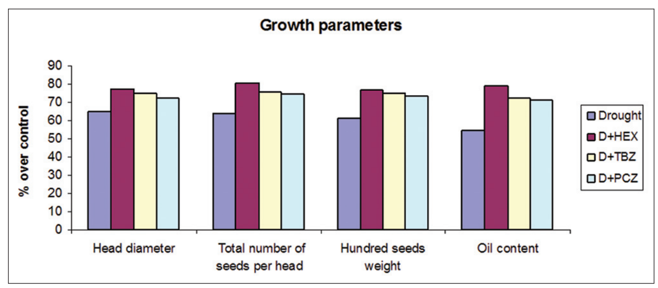

Figure 3: Effect of drought stress and drought with triazoles treatment on yield parameters of sunflower

Hundred Seeds Weight

A hundred seeds weight decreased in sunflower when compared to control. The drought stress decreased hundred seeds weight significantly and it was 61.37% over control. Drought stress with triazole treatments increased the hundred seeds weight when compared to drought-stressed plants, and they were 76.61 in HEX, 74.79 in TBZ, and 73.11% in PCZ over control (Figure 3).

Oil content

Drought stress decreased the oil content to a larger extent and it was 54.59% over control in sunflower. Triazole treatments with drought-stressed plants increased oil content, and they were 78.82 in HEX, 72.08 in TBZ, and 70.94% in PCZ over control (Figure 3).

The 100 seeds weight was reduced significantly in all the treated plants in sunflower when compared to control. Water stress greatly reduced the yield of *Eragrostis curvula* plants (Colom and Vazzana, 2001) and this reduction in grain yield was dependent on the level of defoliation. Water stress during early reproductive growth reduced yield in soybean usually as a result of fewer pods and seeds per pod (Reddy *et al*., 2004). Drought stress reduced on yield and yield components of some sunflower (Farzad *et al*., 2013).

Drought reduced grain yield in soybean and *Vicia faba* (Wu and Wang, 2000) and wheat genotypes (Shao *et al*., 2005a). Water deficit reduced yield in *Capsicum annum* (Dorji *et al*., 2005) and soybean (Kobraee *et al*., 2011). Water deficit significantly affected grain yield in durum wheat (Bogale and Tesfaye, 2011), maize (de Souza *et al.,* 2013), head diameter was decreased significantly with increasing water stress condition in sunflower (Kheybari *et al*., 2013) and chickpea (Yagoob *et al*., 2013). Triazole combination of drought increased the yield when compared to drought, but it was lower than that of control. Similar results were observed in groundnut (Asha and Rao, 2002; Krishnamurthy *et al.,* 2007), *Citrus limon* (Jain *et al.,* 2002), and rice (Pan *et al*., 2013).

Drought stress decreased the oil content when compared to control. The oil content was decreased by drought stress, most likely because of a reduction in photosynthesis and assimilates remobilization. In addition, drought stress reduces the grain filling period and oil content of sunflower significantly (Kheybari *et al*., 2013), qualitative, and quantitative modifications of membrane lipids have been reported under different environmental stresses in *Cicer arietinum* (Matos *et al*., 2010) and lipid degradation was observed in Vigna genotypes (Scotti-Campos *et al*., 2013). Triazoles increased the lipid content when compared to drought, but it was lower than that of control.

Photosynthetic Pigments

Chlorophyll content

Chlorophyll "a"

The chlorophyll content was very much affected by drought stress treatment and it was 69.75% over control on 60th DAS. Triazole to the drought-stressed plants increased the chlorophyll "a" content when compared to the drought-stressed plants and they were 76.15 in HEX, 74.61 in TBZ, and 71.74% in PCZ over control on 60th DAS (Table 3).

Drought stress decreased the chlorophyll content when compared to control. A reduction in chlorophyll content was reported in drought-stressed *H. annuus* (Manivannan *et al.,* 2007). Similar results were observed in rice (Widodo *et al.,* 2003), wheat (Gong *et al.,* 2005), cherry (Centritto, 2005), soybean (Zhang *et al.,* 2007), and in rice (Farooq *et al*., 2009). The chlorophyll content decreased to a significant level at higher water deficits in sunflower plants (Kiani *et al*., 2008), cotton (Massacci *et al*., 2008), and *Vaccinium myrtillus* (Tahkokorpi *et al*., 2007). Triazole treatment to the drought-stressed sunflower plants increased the chlorophyll content when compared to control. Paclobutrazol and drought stress treatment increased the pigments in olive (Thakur *et al.,* 1998). Similar results were observed in triazole treated rose (Jenks *et al.,* 2001). Difenoconazole and tricyclazole increased in *L. esculentum* (Shanmugapriya *et al*., 2013; Mohamadi and Rajaei, 2013).

Chlorophyll "b"

The chlorophyll "b" content was decreased by drought stress and it was 67.11% over control on 60th DAS. Drought stress with triazole treatments increased the chlorophyll "b" content, and they were 74.91 in HEX, 73.89 in TBZ, and 73.22% in PCZ over control on 60th DAS (Table 3). The chlorophyll "b" content was decreased by drought stress. The chlorophyll "b" content of sunflower leaves also increased with age in control and treated plants. Drought-induced a reduction in chlorophyll "b" content of leaves in sunflower when compared to control plants. Similar results were observed in soybean plants (Heerden and Kruger, 2002; De Ronde *et al.,* 2004; and Zhang *et al.,* 2007), maize (Zhang *et al.,* 2006), wheat plants (Nayyar and Gupta, 2006), and rice (Farooq *et al*., 2009). A reduction in chlorophyll content was reported in drought-stressed *V. myrtillus* (Tahkokorpi *et al*., 2007), cotton (Massacci *et al*., 2008), and sunflower plants (Kiani *et al*., 2008).

Triazole treatment to the drought-stressed sunflower plants increased the chlorophyll "b" content when compared to control. Triazole with drought stress treatment increased the pigments in olive (Thakur *et al.,* 1998), *L. esculentum* (Mohamadi and Rajaei, 2013), and rose (Jenks *et al.,* 2001). Similar results were observed in tomato (Thompson *et al.,* 2000), *Kentucky bluegrass* (Wang *et al.,* 2003), maize (Ren *et al.,* 2007), and in *L. esculentum* (Shanmugapriya *et al*., 2013).

Total chlorophyll

Drought stress decreased the total chlorophyll content to a larger extent and it was 68.71% over control on

Table 3: Effect of drought stress and drought with triazoles treatment on chlorophyll content of sunflower (expressed in mg/g fresh weight)

DAS	Control	Drought	D+HEX	D+TBZ	D+PCZ
Chlorophyll "a"					
40	0.314±0.034	0.177±0.048	0.213±0.039	0.203±0.041	0.199±0.046
50	0.371±0.041	0.225±0.044	0.257±0.04	0.256±0.047	0.245±0.035
60	0.453±0.052	0.316±0.039	0.345±0.036	0.338±0.045	0.325±0.038
Chlorophyll "b"					
40	0.149±0.011	0.085±0.016	0.102±0.014	0.101±0.015	0.098±0.013
50	0.201±0.017	0.126±0.019	0.141±0.015	0.138±0.018	0.14±0.019
60	0.295±0.014	0.198±0.015	0.221±0.012	0.218±0.014	0.216±0.016
Total chlorophyll					
40	0.463±0.044	0.262±0.058	0.315±0.053	0.304±0.058	0.297±0.061
50	0.572±0.049	0.351±0.067	0.402±0.048	0.394±0.061	0.385±0.057
60	0.748±0.054	0.514±0.055	0.566±0.044	0.556±0.052	0.541±0.054

Values are mean±SE of seven replicates. SE: Standard error, DAS: Days after showing, HEX: Hexaconazole, TBZ: Tebuconazole, PCZ: Propiconazole

60th DAS. Triazole treatments to the drought-stressed plants increased the total chlorophyll content to a level higher than that of control, and they were 75.66 in HEX, 74.33 in TBZ, and 72.32% in PCZ over control on 60th DAS (Table 3). The chlorophyll "a" chlorophyll "b" and total chlorophyll contents decreased under drought stress condition. Triazole treatments to the drought-stressed plants increased the chlorophyll "a" chlorophyll "b" and total chlorophyll contents when compared to drought-stressed plants. Among the three triazole compounds, the chlorophyll "a", chlorophyll "b", and total chlorophyll content in HEX were high on 60th DAS.

Drought stress decreased the total chlorophyll content to a larger extent when compared with control. A reduction in chlorophyll content was reported in drought-stressed soybean plants (Zhang *et al*., 2006), wheat (Nayyar and Gupta, 2006), *V. myrtillus* (Tahkokorpi *et al*., 2007), *Lysimachia minoricensis* (Galmes *et al*., 2007), Manivannan *et al*., 2007), and cotton (Massacci *et al.,* 2008). However, the stomatal and non-stomatal limitation was generally accepted to be the main determinant of photosynthesis under drought stress (Farooq *et al.,* 2009). Under the condition of water stress, photosynthetic electron transport through PS II is inhibited (Zlatev *et al*., 2010). Triazole treatment to the drought-stressed sunflower plants increased the total chlorophyll content when compared to drought stress. Triazole treated leaves were dark green due to high chlorophyll a and b in potato (Tekaligen *et al.,* 2005) and barley seedlings (Sunitha *et al*., 2004).

Carotenoid content

Drought stress decreased the carotenoid content when compared to control and it was 58.44% on 60th DAS. Drought stress with triazoles increased the carotenoid content, and they were 65.87 in HEX, 63.51 in TBZ, and 64.18% in PCZ over control on 60th DAS (Table 2). The carotenoid content decreased significantly in sunflower of all the treatments when compared to control. Among the drought treatments, the highest reduction was observed in carotenoid content when compared to other treatments. Reduced carotenoid content under drought was reported in wheat (Gong *et al*., 2005) and cherry (Centritto, 2005). Similar results were observed in soybean (Zhang *et al.,* 2006; 2007) and *Litchi chinensis* (Damour *et al*., 2008). Triazoles treated sunflower plants increased the carotenoid content when compared to control and drought-stressed plants. Triamidefon and tricyclazole in *L. esculentum* (Mohamadi and Rajaei, 2013; Shanmugapriya *et al*., 2013). Sunitha *et al.* (2004) reported that the barley seedlings treated with paclobutrazol appeared greener and thicker due to increased pigment contents. Paclobutrazol treatment increased the carotenoid content in *Raphanus sativus* plants (Sankari *et al*., 2006).

Anthocyanin content

Drought stress treatment decreased the anthocyanin content to a larger extent when compared to control, and the decrease was 65.09% over control on 60th DAS. Triazole treatments to the drought-stressed plants increased the anthocyanin content when compared to control and drought-stressed plants and the results were 77.67 in HEX, 75.78 in TBZ, and 74.84% in PCZ over control on 60th DAS (Table 2). The anthocyanin content was decreased by drought stress treatment in sunflower. In drought-stressed plants, the anthocyanin content was low as compared to control plants. Similar results were observed in tomato (Still and Pill, 2004) and wheat plants (Nayyar and Gupta, 2006). Triazole treatment increased the anthocyanin content in sunflower plants, but drought stress has no significant effect on this. Triazoles (HEX and paclobutrazol) treatments increased anthocyanin content in carrot (Gopi *et al.,* 2007). Difenoconazole and tricyclazole increased anthocyanin content of the leaves in *L. esculentum* (Shanmugapriya *et al*., 2013).

CONCLUSION

The growth parameters such as stem length, total leaf area, fresh and dry weight, and the yield parameters such as head diameter, total number of seeds per head and hundred seeds weight decreased under drought stress, but root length increased to a larger extent when compared to control. The triazoles treatment to the drought-stressed plants increased all these parameters when compared to drought-stressed plants. Triazole treatment increased the root length when compared to control, whereas they decreased the shoot length and leaf area. Drought stress lowered the yield components when compared to all other treatments. Triazole treatments to the drought-stressed plants increased the yield components when compared to drought-stressed plants. However, the yields in the triazole treated plants were lower than that of control. Yield components such as head diameter, total number of seeds per head, and hundred seeds weight and oil content decreased with triazoles treatment when compared to control plants. The photosynthetic pigments such as chlorophyll "a" chlorophyll "b", total chlorophyll, carotenoid, and anthocyanin contents of the sunflower leaves were increased in control and treatments. Drought stress decreased photosynthetic pigments content. Triazoles to the drought-stressed plants increased the chlorophyll, carotenoid, and anthocyanin contents when compared to drought stressed plants. Triazoles treatment moderately ameliorated drought stress on pigments content.

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