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A comparative study on impacts of water stress in turmeric varieties Acc 48 and Acc 79

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ABSTRACT

Water stress created in turmeric varieties Acc 48 and Acc 79 by irrigating them in different intervals. Water stress influence on morpho-logical features, physio-logical and yield features of both the varieties was investigated. In this study irrigation treatments divided into three groups. Group A control receives water weekly once. For every two weeks once group B was irrigated and for every three weeks once group C was irrigated. Plants which are under heavy water stress showed gradual reduction in morphological, physiological and in yield parameters, i.e. 'plant height, number of leaves, width of the leaf, fresh and dry weight of rhizome, Relative Growth Rate, Net Assimilation Rate'. Acc 48 & Acc 79 morphological- parameters, physiological and yield parameters was slightly affected in moderate stress compared to control. Among the two Acc 48 resisted water stress in moderate stress condition than Acc 79. In heavy water stress condition, the two varieties severely affected compared to control and moderate stress. Among the two varieties Acc 48 was less affected. In all the treatments Acc 48 was less affected in all aspects except in thin and tuberous roots number. To cope up with water stress length of thin and tuberous roots of both the varieties were increased in heavy and moderate water stress condition. Irrigating turmeric two weeks once showed minor impact on plants than irrigating them three weeks once. In heavy water stress, plants was affected in all morphological, physiological and yield aspects.

Key words: *Acc 48, Acc 79, Relative Growth Rate, Net Assimilation Rate, Water stress*

Introduction

Turmeric (Curcuma) is the popular spice across the globe since ancient times. Especially Turmeric has unique place in Indian lives. Widely using in culinary, Spiritual, one of the key component of herbal preparations. Based on the Active phyto chemical constituents, pharmalogical, biological properties its being treated as king of spices. Turmeric, known as *Pasupu* in telugu, Haldi in Hindi belongs to family Zingiberaceae, is a most wanted spice. This plant botanically called *Curcuma longa*. It's also called as "'Indian Solid Gold"'" and "'Indian Saffron"'. "Curcumin, De-methoxy curcumin, Bis -de methoxy curcumin" are the important active components present in the turmeric. Among these components curcumin is the pivotal component. Curcumin has numerous properties they are" anti-inflammatory, anticancer, antitumor, antibacterial, antioxidant, antidiabetic, antiallergic properties" (Singh *et al.*, 2012; Devassy *et al.*, 2015; Deogade and Ghate 2015; Shehzad *et al.*, 2013).

Water supply can be considered as major factor that influences growth of plant, it also adversely affects production of secondary metabolites. (Randhawa *et al.*, 1992, 1996). Metabolic responses and physiological actions were hugely reduced due to moisture absence (Flevas *et al*., 2002). No water supply to plants leads to drastic changes in growth of plants and in photosynthesis rate. However, some reports which are available confirmed that providing limited water to plants improves the secondary metabolites biosynthesis, accumulation of solutes and enzyme related activities (Singh-Sangwan *et al.,* 2001). Providing varied levels of water to plants i.e (I100, I50 and I0). At level I0 Growth of the plant (i.e height of the plant and plant dry- matter weight) was remarkably decreased (Farshid Vazin., 2013). Depletion in area of leaf, leaf -senescence and reduced cell development was developed due to water undersupply conditions (Kafi and Damghani 2001).

Under supply of water may be primarily influence "the primary, secondary metabolites biosynthesis, plant -lipids, plasma- membrane". Fatty-acids components undergo modifications in several crops due to lack of water. Essential- oil biosynthesis also affected by water stress (Laribi *et al*., 2009; Bourgou *et al.,* 2011; Bettaieb *et al.,* 2011, 2012").

An objective of this study was to analyze the productivity of improved varieties of Curcuma plant (Acc 48, Acc 79) under different water stress conditions.

Water plays a crucial role in plant growth and its production of several crops and medicinal plants was proved by several researchers. Plant height, Total plant fresh weight, Total dry-weight of crop "*Satureja hortensis*" was awfully reduced under soil water debt conditions. (Baher *et al.,* 2002)

"Water use efficiency" (WUE), can be considered as a parameter of crop quality and performance under water stress is an supreme choosen feature. However, plants have emerged numerous actions at molecular level to decrease their resource usage and regulate their growth to adapt to unfavorable climatic conditions (Ahuja *et al.,* 2010; Skirycz and Inze, 2010; Osakabe *et al.,* 2011; Ha *et al.,* 2014).

Water stress directly shows impacts on photosynthesis rate due to the reduced Carbondioxide availability- resulted from closure of stomatal (Chaves *et al.,* 2009), or from alterations in Photosynthetic- metabolism (Lawlor, 2002)

A Study on "*Eragrostis curvula*" plant cultivated under water stress showed that plant number, stem number, dry weight was affected adversely (Colom and Vazzana 2002).A research conducted on rosemary plant which undergone water stress conditions confirmed depletion in morphological parameter and volatile oils percentage was increased. But the yield of volatile oil declined due to less supply of water (Leithy *et al.,* 2006; Hassan *et al*., 2013).

Materials and Methods

A field study was conducted during the year 2019-20 at the University College of Science, Saifabad, Hyderabad. Arid type of climate was recorded in the Hyderabad. Black soil was used for the study. pH of the soil was 6.8. Soil consists available nitrogen, phosphorus, potassium in the concentrations of 560.0, 29.7, 178.5. Pots used during the study with two treatments including control in three replicates in order to study the morphological, physiological and yield parameters of turmeric. Two varieties of turmeric were used for the study they are Acc 48 and Acc 79. They are short duration crops. The healthy rhizomes of turmeric varieties collected from Horticulture and Sericulture Department, Nizamabad, Telangana, India. Sterilization of rhizomes were done by using metaloxin mancozeb (150g/150 ml concentration) by soaking for half an hour. After half an hour, the turmeric rhizomes were dried in shade for around one hour and thirty minutes and sowed in the pots. 60 days after planting, a fungicide named 70% thiophanate methyl were exogenously applied to the saplings.

Each group is divided into following treatments, i.e control giving water in 7 days interval, Moderate water stress giving water in 14 days interval, Heavy water stress giving water in 21 days interval. Plants for observation were randomly selected from control and treatments to study experimental parameters. The parameters choosed for the study is germination percentage where, readings taken at 30, 50, 70, 90 days after introducing the rhizomes to the soils of control and treatment groups, height of the plants, total numbers of thin and tuberous adventitious roots, thin and tuberous roots length ,number of functional leaves, leaf length, leaf width per plant of treatments and control groups were measured in centimeters, Leaf Area was evaluated by Portable Area Meter (LI-COR) Model LI-3,000 in cm^2. Radford (1967) method was followed to measure the plant Net Assimilation Rate, fresh weight of mother rhizome was measured in grams at 180 and 240 DAP by using the electrical balance, length of mother rhizome was measured in grams at 60, 120, 180, 240 DAP, width of mother Rhizome was measured in grams at 240 DAP. Dry weight of mother rhizome was measured in grams at 180 and 240

DAP by using the electrical balance, fresh weight of mother rhizome was measured in grams at 240 DAP. Radford (1967) method was followed to measure the plant Relative Growth Rate. Means were calculated and used for analyzing the morphological, physiological and yield aspects.

Results and Discussion

Morphological parameters

Water stress shows drastic effects on germination percentage of turmeric. At 30th day after plantation both the varieties Acc 48 and Acc 79 showed sixty-six percent germination rate. Acc 48 and Acc 79 showed 100 percent germination from 70th day onwards in control where water is given 7 days once. In case of moderate stress Acc 79 showed poor germination percentage compared to Acc 48 (Fig. 1).

In the heavy stress condition only 33 percent germination on 50th day was recorded in both varieties. In the heavy stress condition Acc 48 germination percentage was less affected than Acc 79.

Plant height varied at different stages of growth of turmeric significantly differed among treatments (Fig. 2). Plant height was measured on 60, 120, 180, 240 DAP. Maximum Plant height was noted in Acc 48 (120 cm at 240 DAP) in control on compared to Acc 79 (82 cm at 240 DAP). Acc 48 (95 cm at 240 DAP) showed maximum Plant height than the Acc 79(63.5 cm at 240 DAP) in case of moderate stress condition. Compared to control the plants which faced moderate stress showed reduced plant height. In case of heavy stress plant height was more affected in Acc 79 (40.2 cm at 240 DAP) compared to Acc 48 (56.9 cm at 240 DAP). Heavy water stress reduced Plant height in both the varieties.

Number of thin and tuberous adventious roots at

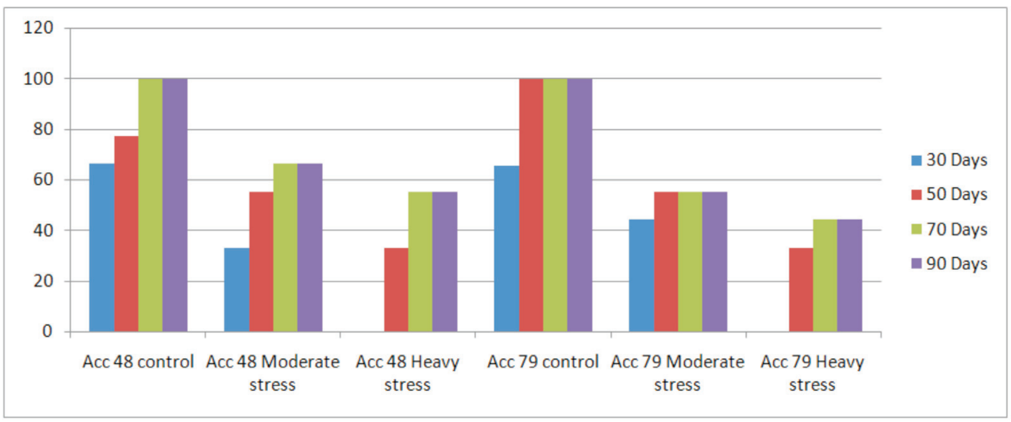

Fig. 1. Effect of irrigation intervals on Germination percentage of Mother Rhizome of Acc 48 and Acc 79 at 30,50,70,90 days after plantation (mean of season 2019 - 2020).

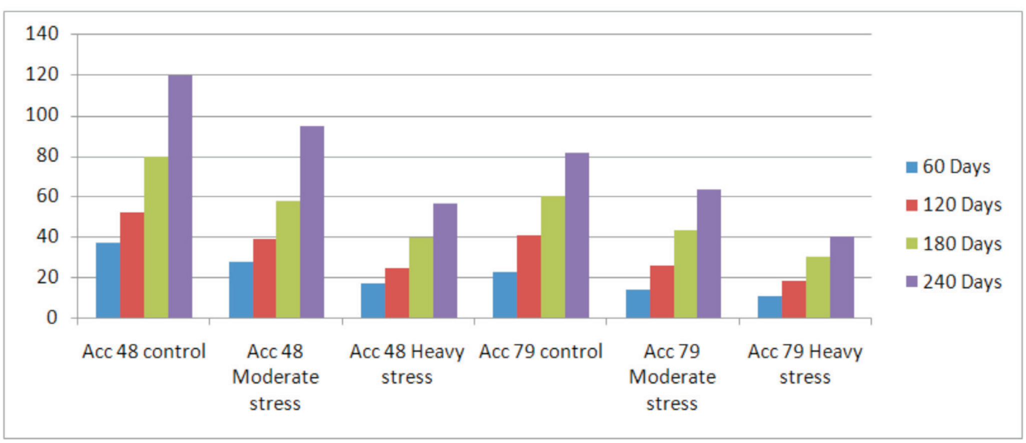

Fig. 2. Effect of irrigation intervals on Plant height of Mother Rhizome of Acc 48 and Acc 79 at 60, 120, 180, 240 days after plantation (mean of season 2019 -2020).

different stages of growth of turmeric significantly differed among treatments (Fig. 3). Number of thin and tuberous adventious roots was measured on 60, 120, 180, 240 DAP. Outrageous number of thin and tuberous adventious roots was noted in Acc 79 (23 at 240 DAP) than Acc 48 (22 at 240 DAP). Maximum number of thin and tuberous adventious roots noted in Acc 79 (16 at 240 DAP) than the Acc 48 (14 at 240 DAP) in case of moderate stress condition. Compared to control the plants which faced moderate stress showed less number of thin and tuberous adventious roots. In case of heavy stress few number of thin and tuberous adventious roots noted in Acc 48 (8 at 240 DAP) than Acc 79(10 at 240 DAP). Heavy stress greatly reduced number of thin and tuberous adventious roots.

Length of thin and tuberous adventious roots at different stages of growth of turmeric significantly varied among treatments (Fig. 4). Length of thin and tuberous adventious roots were measured on 60, 120, 180, 240 DAP. Maxium Length of thin and tuberous adventious roots were recorded in Acc 48 (9.3 cm at 240 DAP) compared to Acc 79 (7.6 cm at 240 DAP) in control.

In moderate stress condition length of thin and tuberous adventious roots were slightly increased in both the varieties compared to control. Among them maximum length observed in Acc 48 (9.7 cm at 240 DAP) than Acc 79 (7.7 cm at 240 DAP). In case of heavy stress condition length of thin and tuberous adventious roots were increased in Acc 48 (10.0 cm at 240 DAP) and Acc 79 (8.0cm at 240 DAP) compared to control and moderate stress. Among the two varieties thin and tuberous adventious roots length was maximum in Acc 48 at 60, 120, 180, 240 days after plantation compared to Acc 79.

Number of leaves per plant at different stages of growth of turmeric significantly differed among

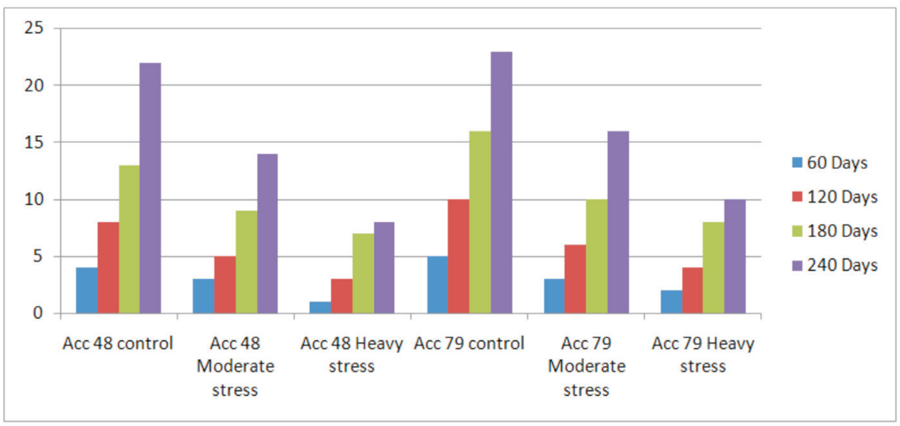

Fig. 3. Effect of irrigation intervals on number of thin and tuberous adventious roots of Acc 48 and Acc79 at 60,120,180,240 days after plantation (Mean of season 2019 - 2020).

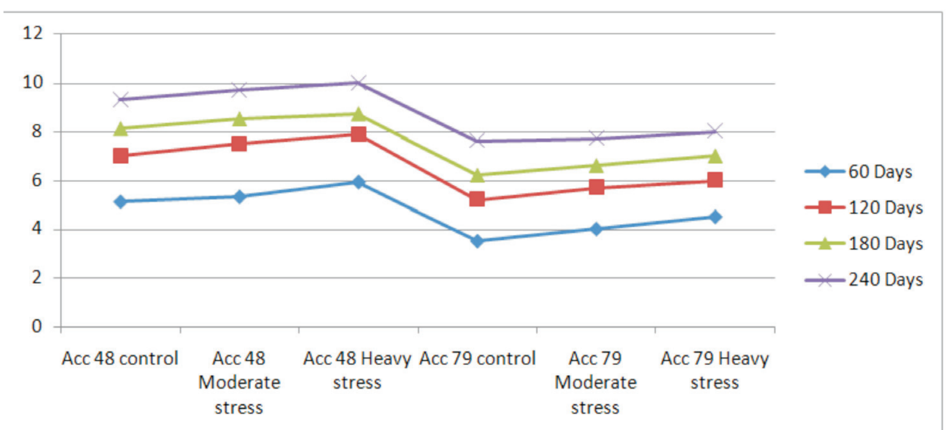

Fig. 4. Effect of irrigation intervals on Length of Thin and Tuberous Adventious roots in cm of Acc 48 and Acc79 at 60,120, 180, 240 days after plantation (mean of season 2019 - 2020).

treatments (Fig. 5). Number of leaves per plant was measured on 60, 120, 180, 240 DAP. Maximum leaf number recorded in Acc 48 (8 at 240 DAP) than Acc 79 (7 at 240 DAP). The number of leaves in Acc 48 and Acc 79 slightly reduced in the plants which were undergone moderate water stress compared to control. Among the two varieties leaves were less affected in Acc 48 (6 at 240 DAP) compared to Acc 79 (5 at 240 DAP). Very few leaves were recorded at 60, 120, 180, 240 days after plantation in the heavy stress condition compared to control and moderate stress. Among the two varieties Acc 48 is less affected. Acc 79 (4 at 240 DAP) was more affected than Acc 48 (5 at 240 DAP) compared to control and moderate stress. The leaves number observed under the extremely stressed treatment (CG 80–85% MAD) are in agreement with the findings on the response of water stress on essential oil of oregano (Auges Gatabazi *et al.,* 2019, Said-A l Ahl *et al*., 2009.

Leaf length of mother rhizome (cm) at different stages of growth of turmeric significantly varied among treatments (Fig. 6). Leaf length was measured on 60, 120, 180, 240 DAP. In control maxium leaf length was noted in Acc 48 (47.5 cm at 240 DAP) than Acc 79 (40.5 cm at 240 DAP). In moderate stress condition leaf length was very less affected in Acc 48 compared to Acc 79 at 60, 120, 180, 240 DAP. Both the varieties Acc 48 (41 cm at 240 DAP) and Acc 79 (33 cm at 240 DAP) were slightly reduced in moderate stress compared to control.

In heavy stress condition leaf length was greatly affected in Acc 48 and Acc 79 compared to control and moderate stress. Among the two varieties leaf length was less affected in Acc 48(35 cm at 240 DAP) compared to Acc 79 (22.2 cm at 240 DAP).

Leaf width of mother rhizome (cm) at different stages of growth of turmeric significantly differed among treatments (Fig. 7). Leaf width was measured on 60,120,180,240 DAP. In control maxium leaf width was noted in Acc 48 (12 cm at 240 DAP) than Acc 79 (11 cm at 240 DAP).

In moderate stress condition leaf width was less affected in Acc 48 than Acc 79 at 60, 120, 180, 240 DAP. Compared to control both the varieties Acc 48

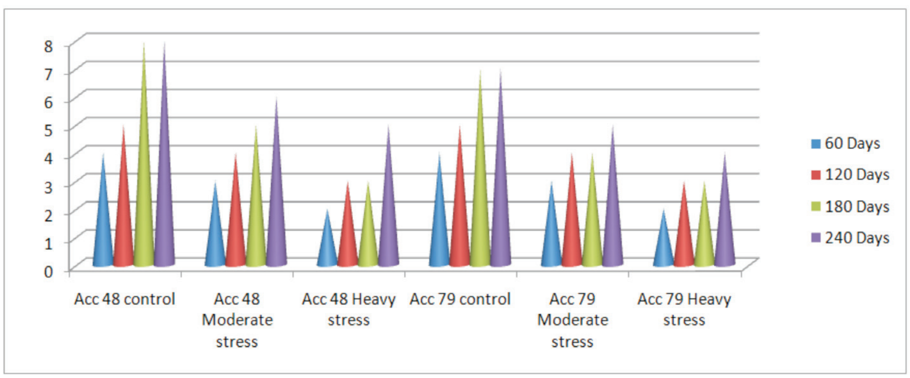

Fig. 5. Effect of irrigation intervals on Number of leaves of Mother Rhizome of Acc 48 and Acc79 at 60, 120, 180, 240 days after plantation (mean of season 2019 - 2020)

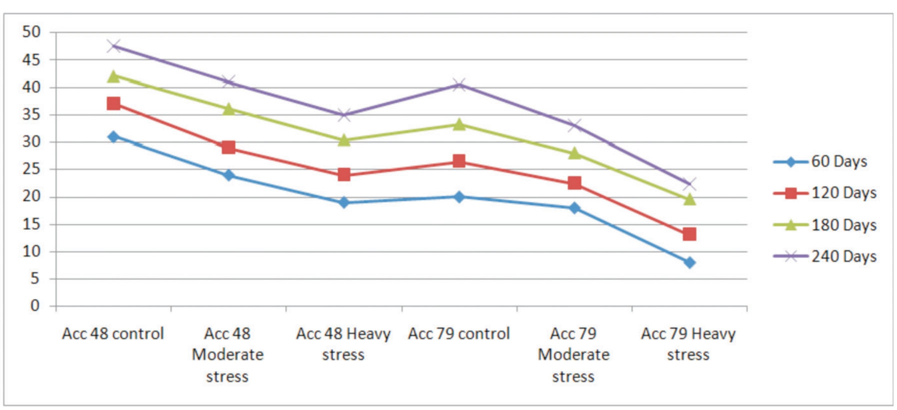

Fig. 6. Effect of irrigation intervals on Leaf Length of Mother Rhizome in cm of Acc 48 and Acc 79 at 60, 120, 180, 240 days after plantation (mean of season 2019 - 2020)

(8.7 cm at 240 DAP) and Acc 79 (8.5 cm at 240 DAP) were slightly reduced. In heavy stress condition leaf width was more affected in Acc 79 and Acc 48 compared to control and moderate stress. Among the two varieties leaf width was less affected in Acc 48 (6.9 cm at 240 DAP) compared to Acc 79 (6.3 cm at 240 DAP).

Physiological aspects

Leaf Area of mother rhizome plant was measured in square centimeters at different stages of growth of turmeric significantly varied among treatments (Fig. 8). Leaf area was measured on 60, 120, 180, 240 DAP. In control maxium leaf area was noted in Acc 48(178 cm^2 at 240 DAP). In moderate stress condition leaf area was less affected in Acc 48 than Acc 79 at 60, 120, 180, 240 DAP. Compared to control both the varieties Acc 48(148 cm^2 at 240 DAP) and Acc 79 (126.5 cm^2 at 240 DAP) were slightly reduced. In heavy stress condition leaf area was more affected in Acc 79 (81 cm^2 at 240 DAP) and Acc 48 (95.5 cm^2 at 240 DAP) compared to control and moderate stress. Among the two varieties leaf area was less affected in Acc 48.

Leaf Area Index of mother rhizome plant at different stages of growth of turmeric significantly varied among treatments (Fig. 9). Leaf area Index was measured on 60, 120, 180, 240 DAP. In control maxium leaf area index was noted in Acc 48 (4.06 at 240 DAP).

In moderate stress condition leaf area index was less affected in Acc 48 than Acc 79 at 60, 120, 180, 240 DAP. Compared to control both Acc 48 (3.7 at 240 DAP) and Acc 79 (3.3 at 240 DAP) were slightly reduced. In heavy stress condition leaf area index was more affected in Acc 79 (2.5 after 240 DAP) and Acc 48 (2.9 at 240 DAP) compared to control and moderate stress. Among the two leaf area index was less affected in Acc 48 than Acc 79.

Net Assimilation Rate of mother rhizome was measured after 240 DAP. It was observed that Acc 79 Net Assimilation Rate was more affected compared to Acc 48 in controls (Fig.10).

In moderate stress condition Net Assimilation Rate of mother rhizome were highly affected in Acc 79 and Acc 48 compared to control. Among the two varieties Acc 48 performance is good than the varieties Acc 48 at 240 DAP.

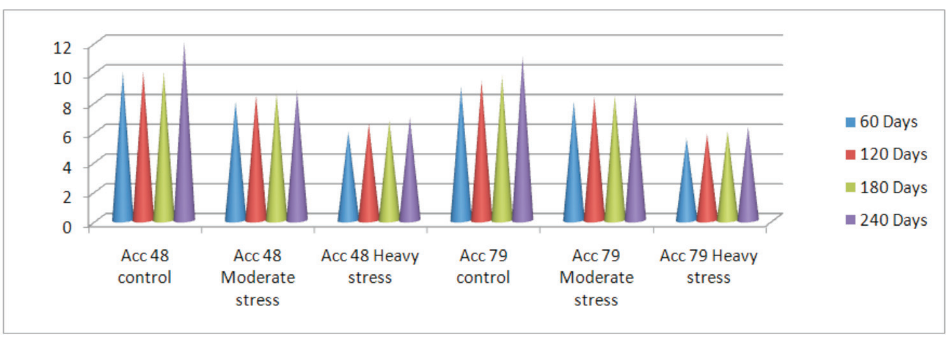

Fig. 7. Effect of irrigation intervals on Leaf Width of Mother Rhizome in cm of Acc 48 and Acc 79 at 60, 120, 180, 240 days after plantation (mean of season 2019 - 2020)

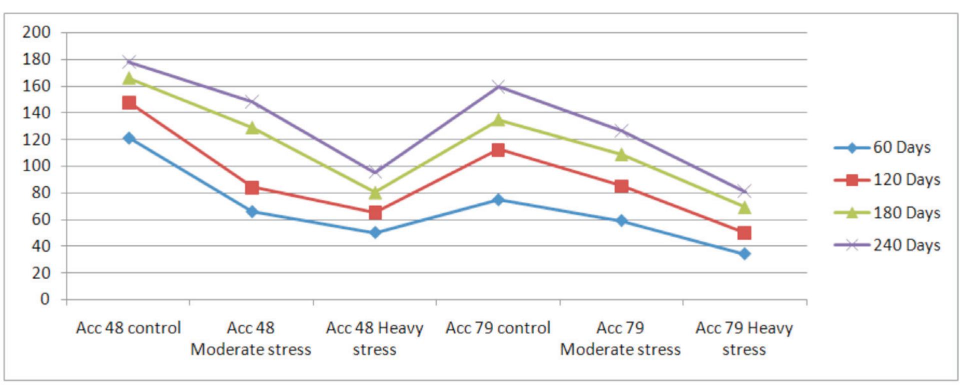

Fig. 8. Effect of irrigation intervals on Leaf Area of Mother Rhizome in cm^2 of Acc 48 and Acc 79 at 60,120,180,240 days after plantation (mean of season 2019 - 2020)

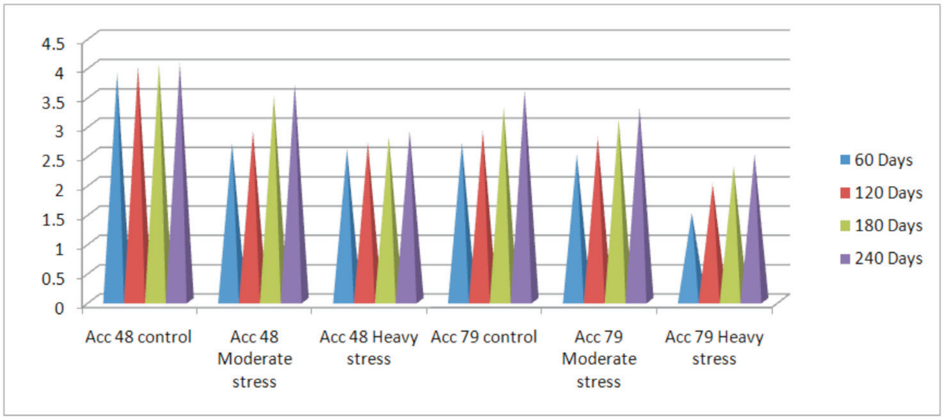

Fig. 9. Effect of irrigation intervals on Leaf Area Index of Mother Rhizome of Acc 48 and Acc 79 at 60, 120, 180, 240 days after plantation (mean of season 2019 - 2020)

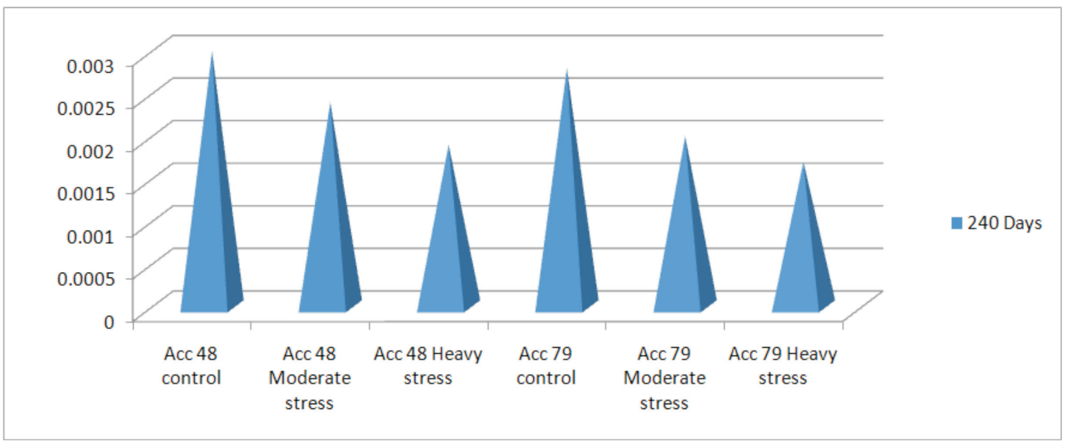

Fig. 10. Effect of irrigation intervals on Net Assimilation Rate of Mother Rhizome of Acc 48 and Acc 79 at 240 days after plantation (mean of season 2019 - 2020)

In heavy stress condition Net Assimilation Rate was affected outrageous in Acc 79 and Acc 48 compared to control and moderate stress. Among the two Net Assimilation Rate was less affected in Acc 48.

Yield aspects

Fresh weight of mother rhizome was measured in grams at different stages of growth of turmeric. Fresh weight was measured on 180, 240 DAP. Their values significantly varied among treatments (Fig. 11). In control maxium fresh weight was noted in Acc 48 (46 g at 240 DAP).

In moderate stress condition fresh weight was less affected in Acc 48 compared to Acc 79 at 180, 240 DAP. Compared to control both the varieties Acc 48 (36 g at 240 DAP) and Acc 79 (26 g at 240 DAP) was slightly reduced.

In heavy stress condition fresh weight was more affected in Acc 48 (26 g at 240 DAP) and Acc 79 (19.0 g at 240 DAP) compared to control and moderate stress .Among the two fresh weight was highly affected in Acc 79 than Acc 48.

Length of mother rhizome was measured in centimeters at different stages of growth of turmeric. Length of mother rhizome was measured on 60, 120, 180, 240 DAP. Their readings were significantly varied among treatments (Fig. 12). Maximum length of mother rhizome was noted in Acc 48 (control 6.5 cm at 240 DAP).

In moderate stress condition length of mother rhizome was highly affected in Acc 79 than Acc 48 at 60, 120,180, 240 DAP. Compared to control both the varieties Acc 48 (5.8 cm at 240 DAP) and Acc 79 (5.1 cm at 240 DAP) were slightly reduced.

In heavy stress condition length of mother rhi-

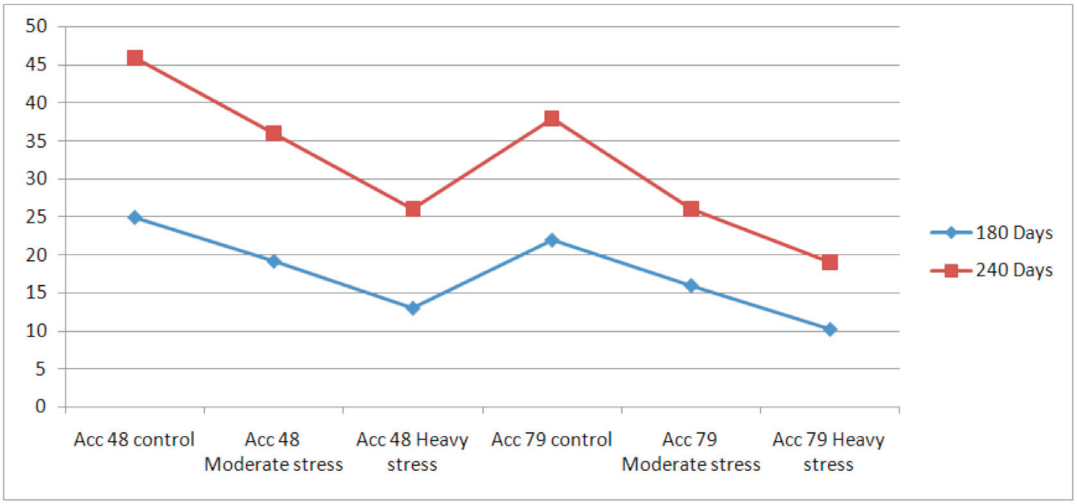

Fig. 11. Effect of irrigation intervals on Fresh weight of Mother Rhizome in g of Acc 48 and Acc 79 at 180, 240 days after plantation (mean of season 2019 - 2020)

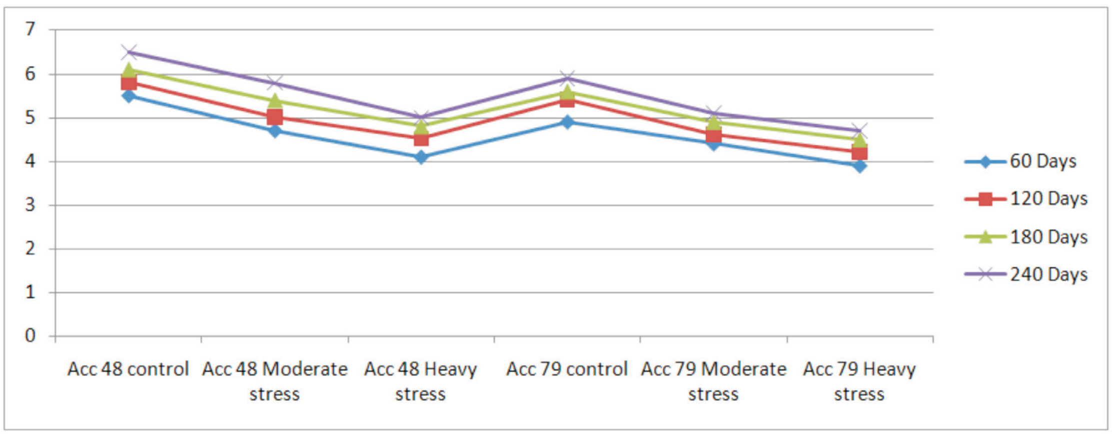

Fig. 12. Effect of irrigation intervals on length of Mother Rhizome in cm of Acc 48 and Acc 79 at 60, 120, 180, 240 days after plantation (mean of season 2019 - 2020)

zome was more affected in Acc 79 (4.7 cm at 240 DAP) and Acc 48 (5 cm at 240 DAP) compared to control and moderate stress. Among the two varieties length of mother rhizome was least affected in Acc 48 than Acc 79.

Mother rhizome width was measured in centimeters at 240 DAP. Their observations were significantly varied among treatments (Fig. 13). In control maximum Width of mother rhizome was recorded in Acc 48 (4 cm after 240 DAP).

In moderate stress condition width of mother rhizome was highly affected in Acc 79 (2.4 cm) than Acc 48 (3 cm) at 240 DAP. Compared to control both the varieties are slightly reduced.

In heavy stress condition Width of mother rhizome was highly affected in Acc 79 (2 cm) and Acc 48 (2.4 cm) compared to control and moderate stress. Among the two varieties mother rhizome width was less affected in Acc 48.

Dry weight of mother rhizome was measured in grams at 180, 240 days of growth of turmeric significantly differed among treatments (Fig. 14). In control maximum dry weight was observed in Acc 48 (10.4 g at 240 DAP).

In moderate stress condition dry weight was slightly affected in Acc 48 compared to Acc 79 at 180, 240 DAP. Compared to control both the varieties Acc 48 (7.5 g at 240 DAP) and Acc 79 (5.2 g at 240 DAP) were slightly reduced.

In heavy stress condition dry weight was highly affected in Acc 48 (5 g at 240 DAP) and Acc 79 (3.6 g at 240 DAP) compared to control and moderate stress. Among the two varieties dry weight was less affected in Acc 48.

Relative Growth Rate of Mother Rhizome was measured at 240 DAP. It was observed that Acc 48 (0.017 at 240 DAP) Relative Growth Rate was less affected than Acc 79 (0.016 at 240 DAP) in control (Fig.15). In moderate stress condition Relative Growth Rate of mother rhizome was affected more in Acc 79 (0.015 at 240 DAP) and Acc 48 (0.016 at 240 DAP) compared to control. Among the two selected varieties Acc 48 performance is good than the varieties Acc 79 at 240 DAP. In heavy stress condition Relative Growth Rate was more affected in both the varieties compared to control and moderate stress .Among the two varieties dry weight was highly affected in Acc 79(0.011 at 240 DAP) compared to Acc 48 (0.012 at 240 DAP).

Research conducted by Ibrahim Bolat *et al*., 2014 also confirmed that enhancing water- stress reduced the Relative Shoot Length and its diameter, total-fresh weight of plant and total dry weight of plant. Leaf Relative Water content and chloro-phyll- index decreased while electrolyte leakage enhanced with the increase of water stress in both rootstocks of "Apple and Quince".

Mean of weight of whole rhizome was measured in kilograms per plant of selected varieties at 240 Days after Plantation (DAP). It was observed that Acc 48 at 240 DAP rhizome whole length was maximum than Acc 79 in control (Fig. 16).

In moderate stress condition weight of whole rhizome were affected more in both the varieties compared to control. Among the two selected varieties Acc 48 rhizome weight was maximum than the variety Acc 79 at 240 DAP.

In heavy stress condition rhizome whole weight was more affected in both the varieties compared to control and moderate stress. Among the two varieties whole rhizome weight was less affected in Acc 48 than Acc 79.

Readings noted were agreed with the results of Leithy *et al.* 2006 who conducted studies on Rosemary plant, "Bettaieb *et al.* 2012 who conducted studies on cumin plant and El-Mekawy (2013) who conducted studies on *Achillea santolina* L. El-Tahir *et al*. (2011) who stated that, this all may be due to vital roles of water- supply at adequate amount of different physiological processes such as photo-synthe-

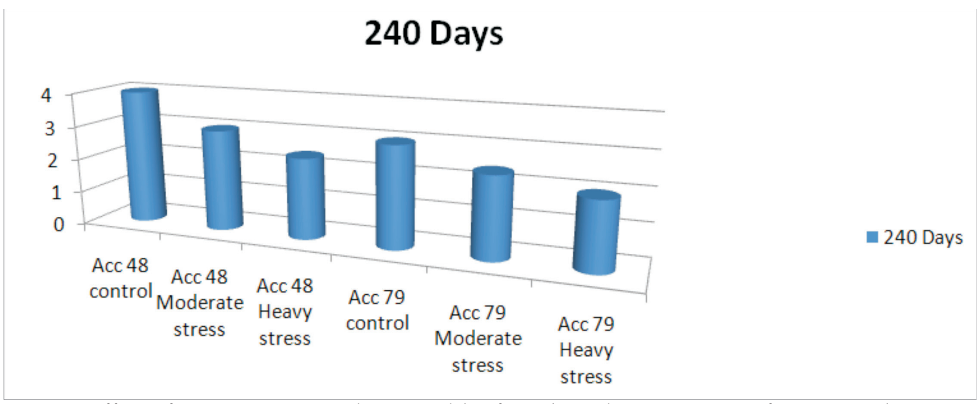

Fig. 13. Effect of irrigation intervals on Width of Mother Rhizome in cm of Acc 48 and Acc 79 at 240 days after plantation (mean of season 2019 and 2020)

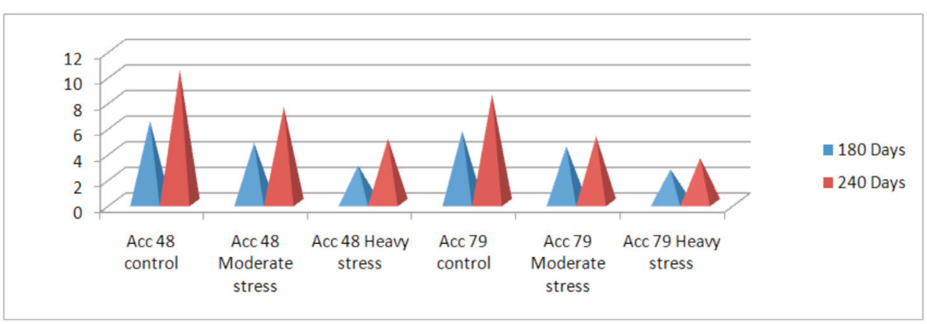

Fig. 14. Effect of irrigation intervals on Dry weight of Mother Rhizome in grams of Acc 48 and Acc 79 at 180, 240 days after plantation (mean of season 2019 and 2020)

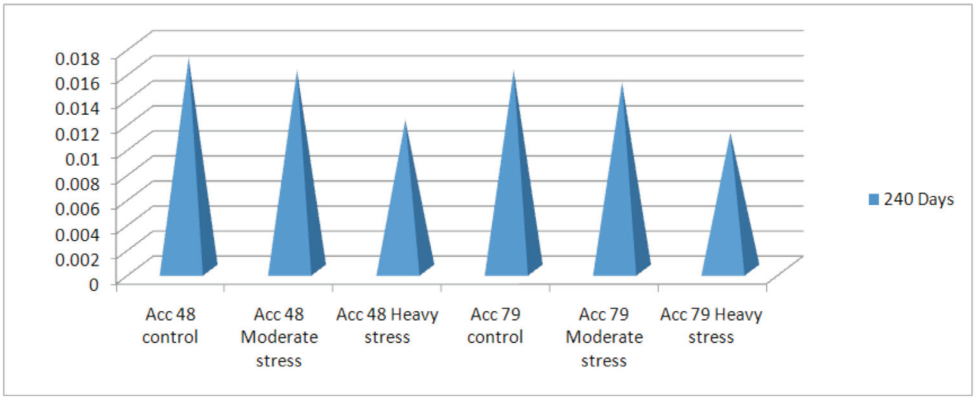

Fig. 15. Effect of irrigation intervals on Relative Growth Rate of Mother Rhizome of Acc 48 and Acc 79 at 240 days after plantation (mean of season 2019 and 2020)

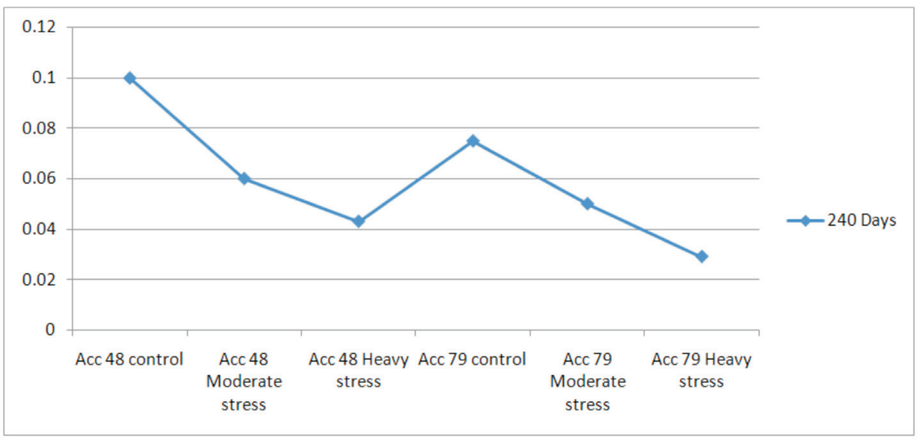

Fig. 16. Effect of irrigation intervals on Weight of Whole rhizome of Acc 48 and Acc 79 in kgs at 240 days after plantation (mean of season 2019 and 2020)

sis, respiration, transpiration, trans-location, enzyme- reaction and cell turgidity occurs simultaneously".

Conclusion

According to the study conducted in the year 2019-20, Acc 48 showed good germination percentage, Plant height, maximum length of thin and tuberous roots, leaf number, leaf length, leaf width, maximum leaf area, leaf area index, length of mother rhizome, width of mother rhizome, fresh weight, dry weight, Relative growth rate and net assimilation rate in control than Acc 79. Acc 79 showed highest number of thin and tuberous roots in control compared to Acc 48. In moderate stress these parameters was slightly reduced in Acc 48 and Acc 79 compared to control. Among the two Acc 48 was less affected at 60, 120, 180, 240 DAP. In heavy water stress condition all these parameters was more affected in Acc 48 and Acc 79 compared to control and moderate stress. Among the two Acc 48 was less affected than Acc 79.

Acc 79 thin and tuberous roots number was more in control and their roots number was less affected in moderate and heavy stress condition than Acc 48. To cope up with water stress length of thin and tuberous roots were increased in heavy and moderate stress in both the varieties. Among two varieties their roots length maximum was recorded in Acc 48. Irrigating turmeric two weeks once showed minor impact on plants than irrigating them three weeks once. In heavy water stress, plants was affected in all morphological, physiological and yield aspects.

References

Ahuja, I., de Vos, R.C., Bones, A. M. and Hall, R.D. 2010.

Plant molecular stress responses face climate change. *Trends Plant Sci.* 15: 664–674. doi: 10.1016/j.tplants.2010.08.002

Auges Gatabazi, Diana Marais, Martin, J. Steyn, Hint, T. Araya, Motiki, M. Mofokeng and Salmina, N. Mokgehle, 2019. Evaluating Growth, Yield, and Water Use Efficiency of African and Commercial Ginger Species in South Africa. *Water:* 11: 548. doi:10.3390/w11030548

Baher, Z.F., Muza, M., Ghorbanli, M. and Rezaii, M.B. 2002. The influence of water stress on plant height, herbal and essential oil yield an decomposition in *Satureja hortensis* L. *Flav Frag*. 6 : 127-32.

Bettaieb, I., Knioua, S., Hamrouni, I., Limam, F. and Marzouk, B. 2011. Waterdeficit impact on fatty acid and essential oil composition and antioxidant activities of cumin (*Cuminum cyminum* L.) aerial parts. *J Agric Food Chem.* 59 : 328-334.

Bettaieb, I.R., Jabri-uroul, I., Hamrouni-Sellami, I., Bourgou, S., Limam, F. and Murzouk, B. 2012. Effect of drought on the biochemical compositon and antioxidant activities of cumin (*Cuminum cyminum* L.). *Seeds. Ind Crop Prod*. 36 (1): 238-245.

Bourgou, S., Bettaieb, I., Saidani, M. and Marzouk, B. 2011. Fatty acids, essential oil and phenolics modifications of black cumin fruit under NaCl stress conditions. *J. Agric Food Chem.* 59 : 3428-3434.

Chaves, M.M., Flexas, J. and Pinheiro, C. 2009. Photosynthesis under drought and salt stress: regulation mechanisms from whole plant to cell. *Ann. Bot.* 103: 551–560. doi: 10.1093/aob/mcn125

Colom, M.R. and Vazzana, C. 2002. Water stress effect on three cultivars of Eragrostis curvula. *Ita J Agron.* 6: 127-32.

Deogade, S. and Ghate, S. 2015. Curcumýn: therapeutýc applýcatýons in systemýc and oral health. *Int. J. Biol. Pharm. Res.* 6(4) : 281–290.

Devassy, J., Nwachukwu, I. and Jones, P. 2015. Curcumin and cancer: barriers to obtain inga health claim. *Nutr. Rev*. 73(3) : 155–165.

El-Mekawy, MAM. 2012. Growth and yield of *Nigella sativa* L. plant influenced by sowing date and irrigation treatments. *Amer-Eur J. Agric Environ Sci*. 12 (4): 499-505.

El-Tahir, B., El-Hawary, A. and Yagaub, S.O. 2011. Effect of different irrigation intervals on wheat (*Triticum aestivum*) in semiarid regions of Sudan. *J Sci Tech.* 12 (3): 75.

Flevas, J. and Medrano, H. 2002. Drought-inhibition of photosynthesis in plants: stomatal and non stomatal limitation revisited. *Ann Bot.* 89 : 183-189.

Farshid Vazin, 2013. Water stress effects on Cumin (*Cuminum cyminum* L.) yield and oil essential Components. *Scientia Horticulturae*. 151 : 135-141.

Hassan, F.A.S., Bazaid, S. and AP, E.F. 2013. Effect of Deficit Irrigation on growth, yield and volatile oil content on *Rosmarinus officinalis* L. Plant. *J Med Plants Stud.* 3: 12-21.

Ha, C. V., Leyva-Gonzalez, M. A., Osakabe, Y., Tran, U. T., Nishiyama, R. and Watanabe, Y. 2014. Positive regulatory role of strigolactone in plant responses to drought and salt stress. Proc. *Natl. Acad. Sci. U.S.A.* 111: 581–856. doi: 10.1073/pnas.1322135111

Ibrahim Bolat, Murat Dikilitas, Sezai Ercisli, Ali Ikinci, and Tahsin Tonkaz, 2014. *Hindawi Publishing Corporation The Scientic World Journal* Volume, Article ID 769732, 8 pages http://dx.doi.org/10.1155/2014/769732

Kafi, M. and Damghan, M.M. 2001. Mechanisms of Environmental Stress Resistance in plants Publicaton Ferdowsi University, Mashhad

Lawlor, D. W. 2002. Limitation to photosynthesis in water-stressed leaves: stomata vs. metabolism and the role of ATP. *Ann. Bot*. 89 : 871–885. doi: 10.1093/aob/mcf110

Laribi, B., Bettaieb, I., Kouki, K., Sahli, A., Mougou, A. and Marzouk, B. 2009. Water deficit effect on caraway (*Carum carvi* L.) growth, essential oil and fatty acid composition. *Ind Crop Prod*. 31: 34-42.

Leithy, S., El-Meseiry, T.A. and Abdallah, E.F. 2006. Effect of/biofertilizer, cell stabilizer and irrigation regime on rosemary herbage oil yield and quality. *J App Sci Res.* 2 (10): 773-779.

Randhawa, G.S., Gill, B.S. and Raychanudhuri, S.P. 1992. Optimizing agronomic requirements of anise (*Pimpinella anisum* L. in the Punjab. *Rescent Advances in Medicinal, Aromatic and Spice Crops. Vol. 2. International Conference, 28-31. January 1989, New Delhi*, India.

Randhawa, G.S. and Mahey, R.K. 1996. Advances in the agronomy and production of in India. *Herbs, Spices Med. Plants.* 3: 71–100.

Skirycz, A. and Inze, D. 2010. More from less: plant growth under limited water. *Curr. Opin. Biotechnol*. 21: 197–203. doi: 10.1016/j.copbio.2010.03.002

Said-A lAhl, H.A.H., Omer, E.A. and Naguib, N.Y. 2009. Effect of water stress and nitrogen fertilizer on herb and essential oil of oregano. *Int. Agrophys.* 23: 269–275.

Shehzad, A., Rehman, G. and Lee, Y. 2013. Curcumin in inflammatory diseases. Int. Union Biochem. *Mol. Biology, Inc.* 39 (1): 69–77.

Singh-Sangwan, N., Farrooqi, A.H.A., Shabih, F. and Sangwan, R.S. 2001. Resultation of essential oil production in plants. *Plant Growth Reg.* 34: 3-21.

Singh, S., Panda, M.K. and Nayak, S. 2012. Evaluation of genetic diversity in turmeric (*Curcuma longa* L.) using RAPD and ISSR markers. *Ind. Crops Prod.* 37: 284–291. 10.1016/j. indcrop. 2011. 12. 022.

Osakabe, Y., Kajita, S. and Osakabe, K. 2011. Genetic engineering of woody plants: current and future targets in a stressful environment. *Physiol. Plant.* 142 : 105–117. doi: 10.1111/j.1399-3054.2011.01451.x