Plant Archives Vol. 14 No. 1, 2014 pp. 161-169 ***ISSN 0972-5210***

EFFECT OF WATER STRESS AT CRITICAL GROWTH STAGES IN DRIP IRRIGATED MUSKMELON (*CUCUMIS MELO* L.) OF SEMI-ARID REGION OF WESTERN MAHARASHTRA, INDIA

D. V. Patil*, K. P. Bhagat and S. Saha

National Institute of Abiotic Stress Management (NIASM), Indian Council of Agricultural Research, Malegaon, Baramati – 413 115 (Maharashtra state), India.

Abstract

The effect of 7 and 14 days water stress on yield and yield components of were studied. The water stress was given during flowering and fruiting phase to the muskmelon variety 'Kundan'. Three factors analysis indicated interactions of growth phase x moisture stress [GP x MS], growth phase x growth regulators [GP × GR], moisture stress x growth regulators [MS x GR] and growth phase x moisture stress x growth regulators [GP × MS × GR]. Water stress was significantly affected number of fruits plant^{-1}, fruit weight, yield plant^{-1} and WUE when irrigation was halted during fruiting phase. However, total soluble sugar was significantly higher in water stress treatment (maximum 13.82 brix). The WUE of control was 0.23 t ha^{-1}cm^{-1} and it was reduced 8.69 % in 7 days and 69.56% in 14 days water stress during flowering. The WUE were markedly reduced from 78.26 to 82.60 % in 7 to 14 days water stress in fruiting phase respectively. The impact of water stress at fruiting stage was more severe than that of flowering stage and also when given for longer period. Farmer can save 56 litres of water plant^{-1} and 7,20,720 litres of water if population is 12,870 plants ha^{-1}. By halting 7 days water during flowering stage, additional 816 plants or 0.06 ha area land may be irrigated that helps in muskmelon crop management. To combat water stress effect application of GA_3 @ 50 ppm mitigated water stress.

Key words : *Cucumis melo*, muskmelon, water stress, deficit drip irrigation, WUE.

Introduction

Muskmelon (*Cucumis melo* L., 2n = 24) is an important fruit crop often cultivated in arid and semi-arid regions of the world, where drought and water stress were the biggest threat. Scheduling irrigation increasingly important in area where there is continuous drought incidence. The adverse impacts of climate change on water sources and severe water stress conditions will affect crop productivity (Boutra, 2010; Xoconostle-Cazares *et al.,* 2010; Ruzana Adibah and Ainuddin, 2011). Water scarcity due to closure of Nira canal as irrigation source and poor precipitation per year in Baramati area of Maharashtra state was unable to grow muskmelon in local area. This necessitates effective use of available water for conventional irrigation practices to ensure optimum crop production. Although, the effects of water stress on growth and yield of different crops have been studied (Tahir and Mehdi, 2001 on sunflower; Aslam and Tahir, 2003 on maize; Hussain *et al.*, 2004 on wheat; Rashidi and Seyfi, 2007 and Kusvuran, 2012 on muskmelon), very little work has been done to study the effect of water stress and their management on muskmelon in semi-arid lands of Deccan plateau of Western Maharashtra, India. Therefore, to maximize return optimization of water use efficiency at critical growth phase is pre requisites of crop plants. Hence the study was conducted to determine the water requirement of plant at critical growth stages that can save water under soil moisture stress conditions in muskmelon.

***Author for correspondence :** E-mail : dvpatil1962@gmail.com

Materials and Methods

Field experiment was conducted in farmer's field by National Institute of Abiotic Stress Management, Indian Council of Agricultural Research, Malegaon Khurd, Baramati – 413 115, Pune district, Maharashtra (India) in semi-arid tract of Deccan plains of Western Ghats. The experimental site is located at 570m amsl altitude in 18°09''30.62'N latitude and 74°30''03.08E longitude in semi-arid climate, where the summers are dry and hot with annual rainfall of 560 mm. The experiment was initiated during January 2012 and continued till end of April 2012. During this period rainfall ranged from 3.5mm – 4.2 mm, rainy days (0.2–0.5), maximum temperature (30.1^{0}C to 38.9^{0}C), minimum temperature (13.0^{0}C–22.2^{0}C), wind speed (5.8–9.6 km/ha), relative humidity at 0830h (60% - 45 %), relative humidity at 1730h (32%-22%), Thunder storms in mean number of rainy days (0.2–0.5), maximum temperature (30.1^{0}C to 38.9^{0}C), minimum temperature (13.0^{0}C – 22.2^{0}C) and dust storms in terms of mean number of days ranged from 0.1–0.1 days. Wind flow was from North to East direction.

Plant material

The seeds of commercially important Muskmelon F_1 hybrid 'Kundan' were sown in micro pots during first week of January 2012 and allowed to germinate in a micro pot tray with a mixture of coir peat: vermiculite substrate (2:1). The plants were grown in growth chamber under controlled conditions. After 16 days of sowing when the seedlings reached to 3 leaf stages (including two germinated cotyledons), the uniform seedlings were transplanted in field during first week of February 2012. The ridges were covered fully with black IRT film (infrared-transmitting wavelength-selective 3 micron) plastic mulch (plate 1a). Drip irrigation system was placed under the plastic mulch. Laterals were placed near the root zone to provide plants uniform application of water and fertigation (plate 1c). Plastic mulch has 8cm diameter size hole, where plant gets sufficient sunlight. Drip irrigation also minimizes the amount of foliage and fruit diseases compared with overhead irrigation.

Plot arrangement

Row × row 2.1m and plant × plant 0.37m distance with plant population {(10000/2.1 * 0.37)} = 12,870 plants ha^{-1} were maintained in trial plots. Experiment was designed in split plot design with four replications. A separate block was maintained for flowering and fruiting phase treatments. Two soil moisture stress levels (7 and 14 days) along with control were applied during two critical growth phases. Muskmelon has five growth stages. First phase is the crop establishment (35 days after sowing; DAS; plate 1b), Phase-II is from the onset of blooming to early fruit setting (20 days after first phase; plate 1d), Phase-III are from early fruit setting to setting of the first two fruits (15 days after second phase; plate 1e), Phase-IV are fruit swelling (20days from third phase), Phase-V are from fruit ripening to harvesting (30 days from fourth phase).

Irrigation schedule

Water was applied through drip irrigation with a discharge of 4 lit hr^{-1} drip^{-1} plant^{-1}. The amount of water requirement was calculated by collecting water discharge hour^{-1} and measured by measuring flask. In complete life cycle of plant 884 litres water per plant was given from I–V growth phase. Initial stage of establishment 1 to 1.5 hours irrigation was applied. Later on plants were irrigated 2 hours per day till harvest in control condition (table 1). Irrigation treatments were designed to induce a range of water stress between emergence and harvest. 7 and 14 days water stress was given when control soil was reached at field capacity after establishment of irrigation.

Flowering and fruiting phases

Flowering phase was considered from the onset of blooming to early fruit setting (plate 1d). 50 percent flowering was recorded after 45 days of seedling transplanting used for application of 7 and 14 days water stress at flowering phase. In 7 days water stress treatment the stopper was closed for 7 days and reopened on 8th day. In 14 days stress treatment water was stopped for 14 days and stopper was reopened on 15th day. In control treatment water was continued throughout crop season. The fruiting phase was considered when plants started early fruit setting to setting of first two fruits after 20 days of flowering (plate 1e). During fruiting phase, 7 days water stress was given by closing the stopper for 7 days and reopened it on 8th day for regular water supply to the plant. In 14 days stress treatment water was stopped for 14 days and irrigation scheduled continued after 15th day. Separate control was maintained for fruiting stage. In 7 days stress treatment water supply was restricted to 56 litres/plant (7 days stress × 8 litres day^{-1} plant^{-1} water requirement). Whereas for 14 days water stress water supply was restricted to 112 litres plant^{-1} (14 days stress x 8 litres day^{-1} plant^{-1} water requirement). The water applied in control condition was 113.80cm. Whereas for 7 and 14 days water stress treatment water applied was 106.6cm and 99.4cm respectively (table 2).

Hormones application

To mitigate water stress two phyto-hormones with each two concentrations [6-BAP (Benzyl amino purine) @ 10 ppm, and 20ppm and GA_3 (Giberellic acid) @ 50ppm and 100ppm] along with control as check was sprayed in both flowering and fruiting phase. Hormonal spray was given one week after imposition of 7 and 14 days water stress. For the preparation of 6-BAP and GA_3 solution, both first dissolved in ethanol and then distilled water was added to get the 50mgl^{-1} concentration. Accordingly, spraying volume was prepared and approximate 95 ml (15000ml /160 plants = 93.75ml) spray plant^{-1} was applied. Control plot were sprayed with water.

Data collection

During harvesting time, a random sample of 5 plants was tagged from each experimental unit and treatment for phenotypic data base purpose. The main components observed in this study were fruits plant^{-1}, fruit weight (g) and total fresh yield plant^{-1} under stress and control conditions. Physiologically matured fruits were collected from flowering, fruiting and control trial plots under 7 and 14 days water stress for quality parameter like total soluble sugar (brix) using refractometer (Hand refractometer, range (0–32), Erma Inc. Tokyo, Japan).

Water use efficiency

Based on total crop yield and water applied, WUE were determined for all treatments. Water use efficiency (WUE) is ratio of total crop yield to total depth of water applied to crop including effective rainfall during its complete growth period (Steyn *et al.*, 2000). The effectiveness of muskmelon crop to use water during its complete growth period (Control) and 7 and 14 days stress was studied. Accordingly WUE was calculated as

$$WUE = CY_{(c)} / \text{Water applied}$$

$$WUE = CY_{(7DS)} / \text{Water applied}$$

$$WUE = CY_{(14DS)} / \text{Water applied}$$

Where,

WUE = water use efficiency (t ha^{-1}cm^{-1})

$CY_{(c)}$ = total crop yield (t ha^{-1}) under irrigation

$CY_{(7DS)}$ = total crop yield (t ha^{-1}) under 7days water stress.

$CY_{(14DS)}$ = total crop yield (t ha^{-1}) under 14 days water stress

WA = total depth of water applied (cm)

All other necessary operations such as pest and weed controls were performed according to recommended package of practices during the crop growth. Data on crop yield and yield components were recorded by using standard procedures.

Statistical analysis

Difference between the irrigation halted treatments and control for yield and yield attributing traits were analysed using Web Agricultural Statistical Packages (WASP-2.0) software, Research Complex (ICAR), Goa, India for three factorial experimental data analysis. The critical difference was compared as suggested by Steel and Torrie (1984) and Le Clerg *et al.*, (1988).

Results and Discussion

Mean sum of squares values showed the significant interactions of growth phase (GP), Moisture Stress (MS) and Growth regulators (GR) for yield and yield contributing traits (table 3). The magnitude of mean performance for number of fruits plant^{-1}, fruit weight, fresh yield plant^{-1} and WUE were decreased in water stress environment when compared to control (table 4). During flowering phase number of fruits were 4.20 plant^{-1} in 7 days and 1.75 fruits plant^{-1} in 14 days water stress which was compared to control (4.25 plant^{-1}) with regression coefficient of $r^2 = 0.77$. Whereas 1.60 fruits plant^{-1} in 7 days and 1.10 fruits plant^{-1} in 14 days water stress at fruiting phase was recorded ($r^2 = 0.86$). Graph shows a markedly downward trend in fruiting phase which entails clear response of reduction to irrigation (fig. 1). The interactions of GP × MS and GP × GR were highly significant. Fruit weight ranged from 459.02g to 207.50g in stress condition over control (475.25g fruit^{-1}). Downward trend with high significant determination factor ($r^2 = 0.94$) were recorded for fruit weight (fig. 2). Fruit weight had significant interaction with GP × MS. At flowering stage, total soluble sugar level went up from 10.97 (control) to 13.40 in 7 days and 13.72 in 14 days water stress with regressions coefficient $r^2 = 0.84$. In fruiting stage brix level increased from 10.65 (control) to 13.57 in 7 days and 13.80 in 14 days water stress ($r^2 = 0.81$). In this function graph becomes steep (figs. 3 and 4). The sugar level interactions of GP × MS, GP × GR and GP × MS × GR were highly significant. The mean crop yield of muskmelon in control plot was 2.02 kg plant^{-1} and in 7 days water stress it was1.92 kg plant^{-1} which maintained yield level during flowering stage with regression coefficient value ($r^2 = 0.81$). However, yield reduction was higher (82.60%) in 14 days water stress at fruiting phase (fig. 5). The interactions of GP × MS, GP × GR and MS × GR are significant for yield plant^{-1}.

In control treatment total amount of water applied was 113.80cm. Whereas, 106.6cm and 99.4cm water was applied in 7 and 14 days water stress, respectively. The WUE of control was 0.23t ha^{-1}cm^{-1} and it was reduced 8.69% in 7 days and 69.56% in 14 days water stress during flowering. The WUE of 7 days water stress at flowering were 0.21t ha^{-1}cm^{-1} higher than that of fruiting phase (0.05t ha^{-1}cm^{-1}). The reduction of WUE was recorded 78.26% in 7days and 82.60% in 14 days water stress at fruiting phase. The WUE had significant interactions of GP × MS and GP × GR are highly significant.

Application of phyto- hormones

GA_3 @ 50ppm had showed significant difference in number of fruits, fruit weight, sugar content and fresh yield. The yield level was increased from 1.92 to 2.92 kg plant^{-1} in 7 days water stress and from 0.56 to 0.76 kg plant^{-1} in 14 day stress at flowering phase. In fruiting stage there was improvement in yield level from 0.45 to 0.59 kg plant^{-1} in 7 days and from 0.30 to 0.37 kg plant^{-1} in 14 days water stress. This indicated that during flowering GA_3 @ 50ppm spray mitigated 7 days water stress to 52.08% and 35.71% in 14 days water stress. However in fruiting stage the effect was lesser than flowering stage to 31.11% to 23.33% at 7 days and 14 days water stress, respectively. The hormonal interaction of GP × GR was highly significant for fruits, total soluble sugar and yield plant^{-1}.

Water stress treatments that affected number of fruits plant^{-1}, fruit weight and yield plant^{-1} crop yield of muskmelon. Possible reason can be deficiency of water during critical phase that slowed physiological process as similar observations are made by Cabello *et al*. (2009) and Ibrahim (2012) on muskmelon. Crop yield and bean size was significantly influenced by deficit irrigation was reported in coffee (Tesfaye *et al*., 2013). Decreased in the performance of morphological traits in deficit irrigation is normally expected evaporative demand of atmosphere. Water stress caused several types of damages like growth inhibition (Kusvuran *et al*., 2011) and metabolic disturbances due to water soluble salts (Franco *et al*., 1997; Mavrogianopoulos *et al*., 1999) on muskmelon crop.

In fruiting stage due to high sensitivity of water stress number of fruits reduced from 63.63% to 75.00% resulted less number of fruits plant^{-1}. Flowering phase was active where reduction number of fruits reduced to 58.82% during 14 days water stress. Onset of blooming and fruit setting is a critical period where differentiation of vegetative and reproductive structures takes place and this period being highly sensitive to water deficit (Barlow *et al*., 1980). The effect of 7 days water stress during flowering phase reduced 1.17% fruits over control indicated less effect of water stress may be due to plant recharging capacity during flowering than that of fruiting phase. During flowering in 7 days water stress condition physiological changes might have occurred which induced mild stress that probably ineffective to bring about considerable reduction in yield. It has been reported that hydraulic signalling (Auge and Moore, 2002) and chemical signals in plant system might have regulated mild stress. Other probable reason is flowering period started after 35 days of crop establishment and continued 20 days from onset of blooming to early fruit setting. This minor shock period gets sufficient time to produce more number of flowers resulting fruit setting which do not much affected on quantitative traits. However 14 days water stress at flowering stage was detrimental as flower bud initiation period already over and another 14 days required for recovering plant where there is initiation of early fruit setting. It is interesting to note that after crop establishment, early fruit setting to setting of first two fruits a critical period is very short (maximum 15 days). Hence onset of blooming to early fruit setting requirement of period are 55 days. Therefore, even 7 days water stress during fruiting phase is critical. Instead of young fruit swelling, dropping of fruits took place. Water stress during fruit setting and swelling period reduced fruit weight drastically. Water deficit during blooming and fruit differentiation phase observed poor fruit setting are in confirmation of earlier findings (Fabeiro *et al*., 2002 and Kusvuran *et al*., 2010) on same crop.

Due to water stress fruit weight reduced from 3.41% to 56.05% reflected lower yield plant^{-1}. Fruit weight reduced from 40.06% to 56.05% in 7 and 14 days water stress in fruiting phase respectively. Cabello *et al*. (2009) in muskmelon reported that under deficit irrigation, the yield was reduced by 22% mainly due to decrease fruit weight. Fruit weight reduced to 12.9% in same crop resulted low yield was reported by Ibrahim (2012) are in confirmation with the present findings.

Though, fruit weight, number of fruits plant^{-1} and yield plant^{-1} was reduced but sugar concentration in fruits becomes higher in a lower irrigation supplement. Brix values in drip irrigation system varied from 10.7 to 12.7 as reported by Dogan *et al.* (2007) on muskmelon are closed to the present findings. Under 14 days water stress condition in fruiting stage sugar concentration was much higher (13.82 brix). Lower irrigation intake, the concentration of sugars in fruit becomes higher are in conformation the fact as reported by Fabeiro *et al.* (2002) and Rashidi and Seyfi (2007) in muskmelon. In general, sugar level of 10–12 brix is considered for good quality.

In control condition crop yield ranged from 25.99 to 26.64 t ha^{-1}. In 7 days water stress at flowering phase crop yield was 24.71 t ha^{-1}, which is much higher than that of crop yield obtained in 7 days (5.79 t ha^{-1}) and 14 days (4.63 t ha^{-1}) water stress at fruiting phase respectively. The higher value of crop yield obtained at regular irrigation and 7 days water stress during flowering phase might be due to adequate moisture in active root zone, sufficient moisture conservation, better utilization of nutrients and fast recharge mechanism. Low crop yield obtained may be due to infrequent application of water during water stress resulting in a lack of moisture in active root zone, inadequate moisture conservation and poor nutrient utilization as reported (Tahir and Mehdi, 2001)

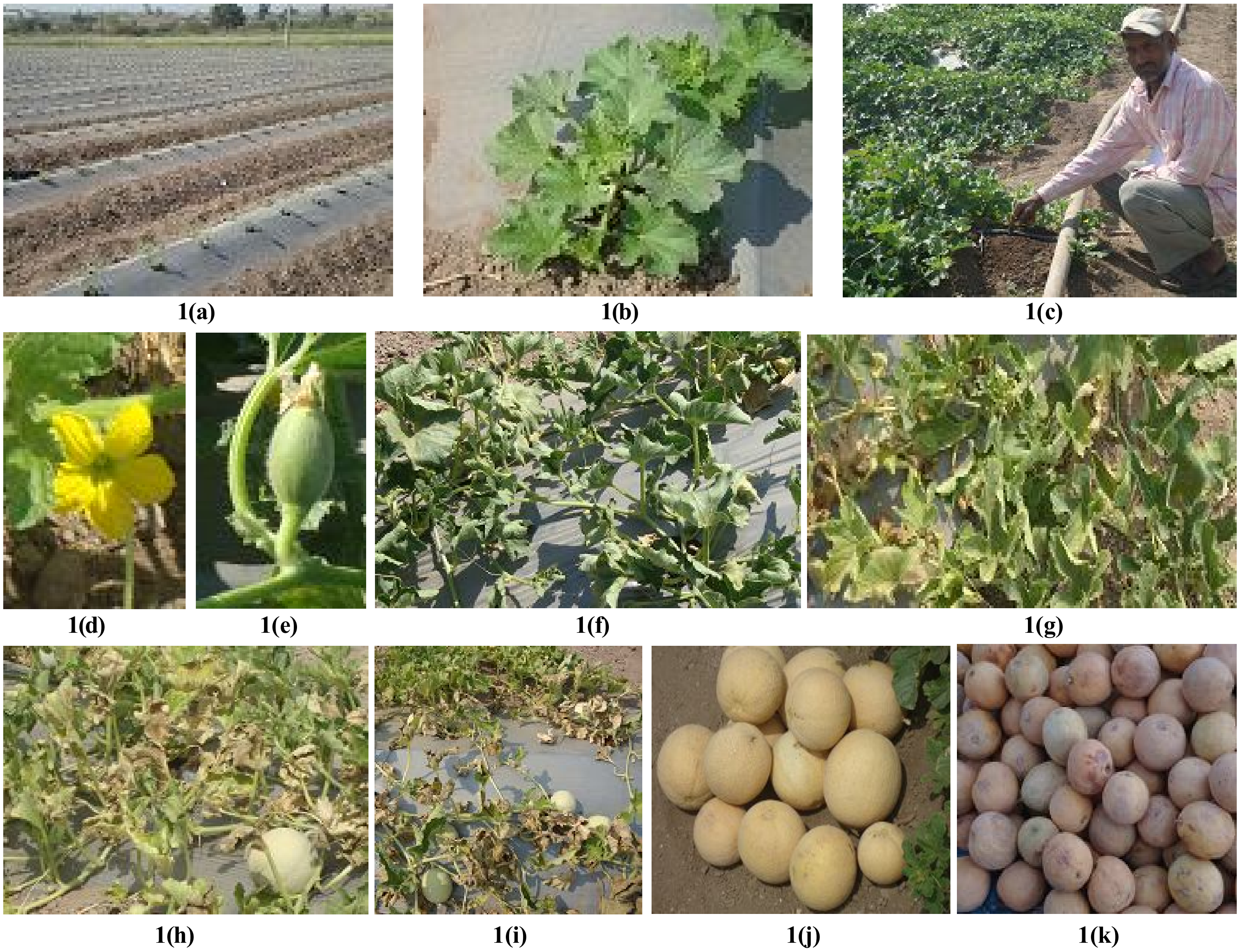

Plate 1 : Farmer's field – Muskmelon.

1(a) : IRT black film mulching, **1(b)** : 35 days old seedling (DAS), **1(c)** : Water stress by halting 7 and 14 days drip irrigation, **1(d)** : Water stress during flowering, **1(e)** : Water stress during fruiting phase, **1(f)** : Effect of 7 days water stress during flowering, **1(g)** : Effect of 14 days water stress during flowering, **1(h)** : Effect of 7 days water stress during fruiting, **1(i)** : Effect of 14 days water stress during fruiting, **1(j)** : Fruits collected in 7 days water stress during flowering phase, **1(k)** : Fruits collected in 14 days water stress during fruiting.

on maize, (Aslam and Tahir, 2003) on wheat, (Ahmad *et al.,* 2003 and Kumaga *et al*., 2003) on legumes and (Fabeiro *et al*., 2002; Rashid and Seyfi, 2007) on muskmelon. It is clear from the study that deficit irrigation relating to water stress take place in plant at a certain phenological stages loosed production, shape, size and quality.

The WUE of control treatment were significantly higher (0.23t $ha^{-1}cm^{-1}$) than other treatments. The 7 days water stress in flowering phase treatment attained WUE of 0.21t ha^{-1} cm^{-1} with the fact that muskmelon plant has adaptation to cope up with moisture stress and recharged plant very fast with less reduction of plant vigour. The lowest WUE (0.04 t $ha^{-1}cm^{-1}$) realized for 14 days water stress markedly affected on crop yield during fruiting phase indicated poor response of plant system. Plant unable to recover due to disturbances in metabolic pathway, sufficient water might have not furnishes to suitable medium for many biochemical reactions and lastly it was reflected on number of fruits, fruit weight and yield $plant^{-1}$ as reported in earlier findings of Rahman *et al.,*(2004) in maize crop. Study conducted by Rashidi and Seyfi, (2007) on muskmelon pointed out that 30% available water deficit affected number of fruits $plant^{-1}$, fruit weight and muskmelon yield and more effective in improving WUE confirmed the present findings. Sufficient water must be present in active root zone for fruit setting, swelling and ripening, evapo-transpiration, nutrient absorption by roots, root growth, soil microbiological and

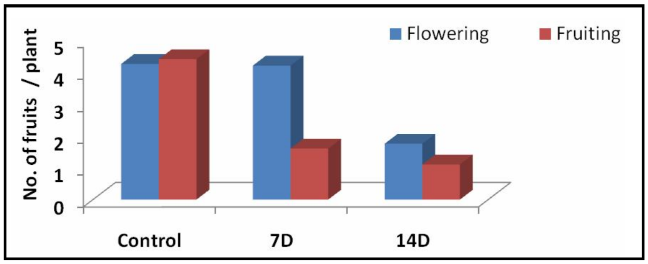

Fig. 1 : Relationship between 7 and 14 days water stress and number of fruits plant^{-1} in flowering and fruiting stage.

Total Soluble Sugar

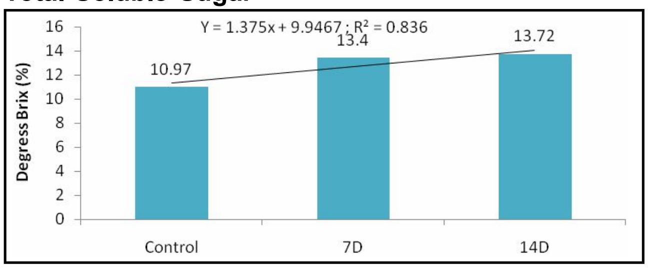

Fig. 3 : Relationship between 7 and 14 days water stress and sugar in flowering stage.

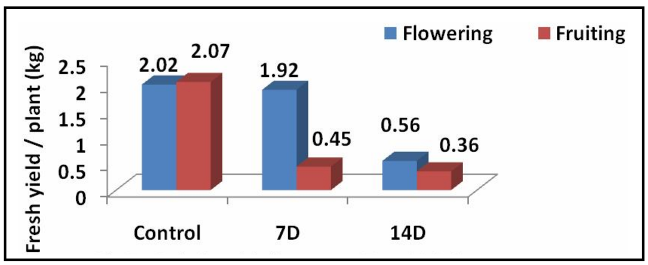

Fig. 5 : Relationship between 7 and 14 days water stress and fresh yield plant^{-1} in flowering and fruiting.

chemical processes that aid in decomposition of organic matter and mineralization of nutrients that sustain crop growth on a particular field. Physiological changes in plants, which occur in response to water stress conditions decrease photosynthesis and respiration as studied in sunflower resulted overall decreased in yield production (Hall *et al.*, 1990). Findings of Sammis *et al.* (2000) in onion crop reported that deficit irrigation results water

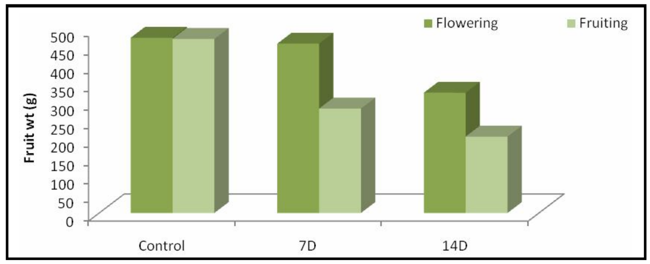

Fig. 2 : Relationship between 7 and 14 days water stress and fruits weight in flowering and fruiting stage.

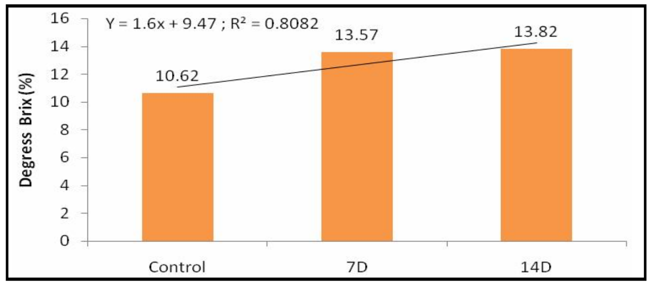

Fig. 4 : Relationship between 7 and 14 days water stress and sugar in fruiting stage.

stress and reduced crop yields. Hence water must be applied frequently to avoid crop water stress and adequately to recharge the active root zone. In the present investigation, available water deficit was more effective in 7 days water stress during flowering phase and improved WUE. The sensitivity of 14 days water stress during fruiting stage was significantly higher than that of flowering stage. Dogan *et al*. (2007) optimized irrigation water using six different levels (0, 25, 50, 75, 100 and 125% of 'class A' pan evaporation rates in muskmelon and found that highest yield level was maintained at 92% of 'class A pan' in surface drip irrigation system. The decrease of irrigation amount affects significantly both melon yield and WUE only when the irrigation amount is less than that applied in treatment and 30% reduction in total water was sufficient to alter significantly the melon yield (Silva *et al*., 2007). In general plant has capacity and water stress defence mechanism to tolerate certain

Table 1: Crop stages and irrigation schedule in control plots.

Crop stages		Duration (days)	Irrigation schedule			
			Rate (litre hr^{-1} drip^{-1}plant^{-1})	hr	days	Total (litre)
Stage I	Establishment	35	4	1	15	60
			4	1.5	8	48
			4	2	12	96
Stage II	Blooming to early fruit setting	20	4	2	20	160
Stage III	Early fruit setting to first two fruit setting	15	4	2	15	120
Stage IV	Fruit swelling	20	4	2	20	160
Stage V	Fruit ripening to harvesting	30	4	2	30	240

Table 2 : Water applied and water use efficiency during water stress treatment.

Treatments	Water applied (cm)	WUE (t ha^{-1} cm^{-1}) (Figures in bracket represent percentage reduction in WUE compared to control)
Control	113.80	0.23
7 Days water stress during flowering	106.6	0.21 (8.7)
7 Days water stress during fruiting	106.6	0.05 (78.3)
14 Days water stress during flowering	99.4	0.07 (69.6)
14 Days water stress during fruiting	99.4	0.04 (82.6)

level of water stress and recharge root zone as happened in 7 days of water stress during flowering stage (plate 1f). Beyond certain stress level plant unable to tolerate stress and there is no further recovery rather plant deteriorates it plant vigour in term of fruit size, fruit weight and yield (plates 1g, 1h & 1i). Once plant entered into reproductive phase its water requirement is very high to have continuous water flow to dissolve accumulated solutes for fruit growth and enlargement. Maintenance of plant water status is a fundamental phenomenon for the maintenance of normal growth of plants under stressful environment as reported by Ali and Ashraf (2011) on maize crop. Leaf water potential may be one of the reasons where during drought, leaves are subjected to both heat and water deficiency stress as pointed out on sugar beet crop (Clarke *et al*., 1993). The plants under 14 days water stress during fruiting stage turned yellowish, leaf curling took place, brown spot appears on leaves indicated permanent wilting of cells and plant

Table 3: Mean sum of squares for three factors analysis of variance of yield and yield components of muskmelon.

Source of variation	df	Number of fruits plant $^{-1}$	Fruit weight (g)	TSS (brix)	Yield (kg $plant^{-1}$)	WUE
Replications	3	0.04	548.29	0.06	0.03	0.01
Growth phases (GP)	1	54.99**	191600.28**	1.92**	19.28**	0.29**
Moisture Stress (MS)	2	92.88**	207523.30**	16.74**	34.99**	0.39**
Growth Regulators (GR)	4	15.02**	13831.73**	14.97**	5.45**	0.08**
GP x MS	2	22.47**	55363.80**	0.40**	7.81**	0.11**
GP x GR	4	0.43**	1354.27NS	1.09	0.31**	0.01**
MS x GR	8	0.28NS	872.16NS	0.21NS	0.09**	0.01NS
GP x MS x GR	8	0.36	2307.80NS	0.62**	0.08NS	0.01NS
Error	87	0.14	1282.26	0.10	0.04	0.01
Total	119					

*Significant at 0.05; ** significant at 0.01 probability, df : degree of freedom

Table 4: Reduction in yield and yield components under 7 days and 14 days water stress

Treatments	Flowering stage			Fruiting stage		
	Control	Water stress (days)		Control	Water stress (days)	
		7	14		7	14
Number of fruits $plant^{-1}$	4.25	4.20 (-1.17)	1.75 (-58.82)	4.40	1.60 (-63.63)	1.10 (-75.00)
Fresh fruit weight (g)	475.25	459.02 (-3.41)	326.25 (-31.35)	472.15	283.00 (-40.06)	207.50 (-56.05)
TSS (brix)	10.97	13.40 (+22.15)	13.72 (+20.04)	10.65	13.57 (+21.51)	13.82 (+22.93)
Fresh yield (kg $plant^{-1}$)	2.02	1.92 (-4.95)	0.56 (-72.27)	2.07	0.45 (-78.26)	0.36 (-82.60)
WUE (t ha^{-1} cm^{-1})	0.23	0.21 (-8.69)	0.36 (-69.56)	0.23	0.05 (-78.26)	0.04 (-82.60)

Figures in parenthesis indicate percentage changes in the parameter values (negative sign implies reduction and positive sign indicates increase compared to control.

enable to recover (plates 1h & 1i). Probably plant might have applied defence mechanism which was not trigger during 14 days water stress at fruiting stage (plate 1k). However during 7 days water stress slight leaf curling was noticed and when irrigation regulated on 8th day leaf recovered completely from temporary wilting gives opportunities to manipulate irrigation scheduled in flowering phase. Mohammadian *et al.* (2001) explained plant defence mechanism suggested that under drought conditions, sugar beet leaves wilt in response to water deficiency and tend to lay flat on soil and thus increase effective area exposed to sun, therefore reduction in transpiration rate of such leaves and leaf temperature increased. Ibrahim (2012) studied muskmelon genotypes under irrigated and drought conditions where water stress were started after first irrigation and created by reducing the frequency of irrigation watering by one half to that of irrigated crop showed significant water levels x genotypes interactions for fruit weight, number of fruits and yield. Similar type of growth phase (GP) × moisture stress (MS) interactions was found highly significant for all studied traits are in agreement with Ibrahim (2012) on muskmelon. Lower yield in reproductive phase probably because of reduced rate of physiological activities associated with total dry matter production and its partitioning to fruits due to water deficit at critical berry development stages (Tesfaye *et al*., 2013). Severe disturbance of physiological process and reduction in growth and productivity of plants due to long-term water deficits has been well documented and such a prolonged drought would be potentially most damaging to crop yield when it occurs at reproductive stages.

Application of phyto- hormones

Due to GA_3 application fruit size and fruit setting was increased resulted higher yield and highly effective at flowering phase. Reason may be GA_3 had more efficient stress protection mechanism to reduce water stress effect in plant cell when plants are under stressful environment. It has been generally known that tolerance to drought usually involves the development of low osmotic potential mainly because of accumulation of solutes in the cells as studied in sunflower (Ashraf and Oleray, 1996). Gibberellic acid is labelled for stimulation and regulates osmotic potential during fruit setting in muskmelon. Though it is well reported that cytokinin 6-BAP (50mg l^{-1}) reduces and mitigate effects under severe drought stress (50% field capacity) in maize (Ali *et al*., 2011), it was not effective than that of GA_3 in muskmelon probably low dose of 6-BAP sprayed, where the plant could not responded.

Conclusion

There is a possibility for plant physiological process can be temporarily deviate from normal metabolic activities in 7 days water stress at flowering stage and reduced irrigation load without affecting plant vigour. Tolerance of 7 days water stress at flowering stage has its importance in term of saving 56 litres of water plant^{-1}. It is clear from the study that flowering is only a critical stage where irrigation schedules can be restricted and plant system can be recharged. If yield level of control treatment compared with 7 days water stress during flowering phase, the difference is of 100g plant^{-1} (1.28 t ha^{-1}). However, to grow muskmelon in a hectare land 11,377,080 litres water is required. Hence by saving 7,20,720 litres of water per hectare extra 816 plants or 0.06 hectare land can be irrigated. Farmers can get additional yield of 1567kg from these extra 816 plants. This mechanism and farmer's oriented water stress management technology may save water whenever there is a closure of irrigation source (Nira canal) in Deccan plateau semi-arid region of Maharashtra and help farmers to grow muskmelon by scheduling irrigation. Further studies were emphasized that how plant recovered metabolic pathway after 7 days of water stress at flowering stage. But 7 days water stress given during fruiting stage was detrimental is opening pathway to conduct research at molecular level. Therefore, halting irrigation at flowering phase appears to be more effective for muskmelon production where frequent water scarcity and recurrent drought occurred.

References

Ahmad, R., S. Qadir, N. Ahmad and K. H. Shah (2003). Yield potential and stability of nine wheat varieties under water stress conditions. *Int. J. Agric. Biol.*, **1** : 7 – 9.

Ali, Q. and M. Ashraf (2011). Induction of drought tolerance in maize (*Zea mays* L.) due to exogenous application of trehalose: Growth, photosynthesis, water relation and oxidative defence mechanism. *J. Agron. Crop Sci.*, **194(4)** : 258 – 271.

Ali, Z., S. M. A. Basra, H. Munir, A. Mohmood and S. Yusuf (2011). Mitigation of drought stress in Maize by natural and synthetic growth promoters. *J. Agric. Soc. Sci.*, **7(2)** : 56 – 62.

Ashraf, M. and J. W. Oleary (1996). Effect of drought stress on growth, water relations and gas exchange of two lines of sunflower differing in degree of salt tolerance. *Int. J. Plant Sci.*, **157(6)** : 729 - 732.

Aslam, M. and M. H. N. Tahir (2003). Correlation and path coefficient analysis of different morpho- physiological traits of maize inbreds under water stress condition. *Int. J.Agric. Biol.*, **4** : 446 – 448.

Augé, R. M and J. L. Moore (2002). Stomatal response to nonhydraulic root-to-shoot communication of partial soil drying in relation to foliar dehydration tolerance. *Environmental and Experimental Botany*, **47** : 217-229.

Barlow, E. W. R., R. E. Munns and J. C. Brady (1980). Drought responses of apical meristems. In: Turner, N.C. and P.J. Kramer. (eds.), Adaptation of plants to water and high temperatures stress. Wiley, New York, pp. 191-205.

Boutraa, T. (2010). Improvement of water use efficiency in irrigated agriculture: A review. *Agron*, **9** : 1- 8.

Cabello, M. J., M. T. Castellanos, F. Romojaro, C. Martinez-Madrid and F. Ribas (2009). Yield and quality of melon grown under different irrigation and nitrogen rates. *Agric. Water Manag*., **96** : 866 - 874.

Clarke, N., H. Hetschkun, C. Jones, E. Boswell and H. Marfaing (1993). Identification of stress tolerance traits in sugar bet. In : Interacting stress on plants in a changing climate. Jackson, MB and Black CR (Eds.) Springer-Verlag, Berlin., pp. 511-524.

Dogan, E., H. Kimak, K., Berekatoglu, L. Bilgel and A. Surucu (2007). Water stress imposed on muskmelon (*Cucumis melo* L) with surface and drip irrigation systems under semi-arid climatic conditions. *Irrigation Sci.* Springer – Verlag, **10** : 271-279.

Fabeiro, C., F. Martin, de Santa Olalla and J.A. de Juan (2002). Production of Muskmelon (*Cucumis melo* L.) under controlled deficit irrigation in a semi-arid climate. *Agricultural Water Management*, **54** : 93 -105.

Franco, J. A., J. A. Fernandez and S. Banon (1997). Relationship between the effect of salinity on seedling leaf area and fruit yield of six muskmelon cultivars. *Hort. Sci*., **32(4)** : 642-644.

Hall, A. J., D. J. Conner and D. M. Whitfield (1990). Root respiration during grain filling in sunflower : the effect of water stress. *Plant Soil*, **121** : 57-66.

Hussain, A., M. R. Chaudhry, A. Wajid, A. Ahmad, M. Rafiq, M. Ibrahim and A. M. Goheer (2004). Influence of water stress on growth, yield and radiation use efficiency of various wheat cultivars. *Int. J. Agric. Biol*., **6** : 1074-1079.

Ibrahim, E. A. (2012). Variability, heritability and genetic advance in Egyptian sweet melon (*Cucumis melo* var. *Aegyptiacus* L) under water stress condition. *Int. J. Plant Breeding & Genetics*, **6(4)** : 238-244.

Kumaga, F. K., S. G. K. Adiku and K. Ofori (2003). Effect of post-flowering water stress on dry matter and yield of three tropical grain legumes. *Int. J. Agric.Biol.*, **4** : 405-407

Kusvuran, S., H. Y. Dasgan and K. Abak (2011). Responses of different melon genotypes to drought stress. Yuzuncu Yil University, *J. Agric. Sci*., **21(3)** : 209-219.

Kusvuran, S., H. Y. Dasgan, S. Kucukkomurcu and K. Abak (2010). Relationship between drought tolerance and stomata density in melon. *Acta Hort*. (ISHS), **871** : 291-300.

Kusvuran, S. (2012). Effects of drought and salt stresses on growth, stomatal conductance, leaf water and osmotic potentials of melon genotypes (*Cucumis melo* L.). *Afr. J. Agric. Res*., **7(5)** : 775-781.

Le Clerg, E.L., W. H. Leonard and G.A. Clark (1988). Field plot techniques, 2nded., Burgess, Minneapolis, pp.50-54.

Mavrogianopoulos, G. N., J. Spanakis and P. Tsikalas (1999). Effect of carbon dioxide enrichment and salinity on photosynthesis and yield in melon. *Sci. Hort*., **79** : 51-63.

Mohammadian, R., F. R. Khoyi, H. M. Rahimian Moghaddam, K. Ghassemi–Golezani and S. Y. Sadeghian (2001). Effects of early season drought on stomatal conductance, leaf – air temperature difference and proline accumulation in sugar beet genotypes. *J. Agric. Sci.Technol*., **3** : 181-192.

Rahman, M. U., S. Gul and I. Ahmad (2004). Effects of water stress on growth and photosynthetic pigments of corn (*Zea mayz* L.) cultivars. *Int. J. Agric. Biol.*, **4** : 652-655.

Rashidi, M. and K. Seyfi (2007). Effect of water stress on crop yield and yield components of cantaloupe, *Int. J. Agri. and Biology*, **9(2)** : 271-273.

Ruzana Adibah, M. S. and A. N. Ainuddin (2011). Epiphytic plants responses to light and water stress. *Asian J. Plant Sci*., **10** : 97-107.

Sammis, T. W., M. S. Al-jamal, S. Ball and D. Smeal (2000). Crop water use of onion. *In: Proceeding of 6th International Micro-irrigation Congress, Micro- irrigation Technology for Developing Agriculture.* 22 - 27 October (2000), South Africa.

Silva, D. B. B., J. A. Ferreira, T. V. R. Rao and V. D. P. R. D. Selva (2007). Crop water stress Index and Water – Use Efficiency for Melon (*Cucumis melo* L.) on different irrigation regimes, *Agril., J. Medwell Journals*, **2(1)** : 31-37.

Steel, R. G. D. and J. H. Torrie (1984). *Principles and Procedures of Statistics: A Biometrical* McGraw Hill Book Co., Inc., New York, USA.

Steyn, J.M., D.U. Plessis, H.F. Fourie, P. and T. Roos (2000). Irrigation scheduling of drip irrigated potatoes. *In: Proceeding of 6thInternational Micro-irrigation Congress, Micro-irrigation Technology for Developing Agriculture,* 22 - 27 October 2000, South Africa.

Tahir, M.H.N. and S.S. Mehdi (2001). Evaluation of open pollinated sunflower (*Helianthus annuus* L.) population under water stress and normal conditions. *Int. J. Agric. Biol.*, **2** : 236-238.

Tesfaye, S. G., M. R. Ismail, H. Kausar, M. Marziah and M. F. Ramlan (2013). Plant water relations, crop yield and quality of Arabica coffee (*Coffea arabica*) as affected by supplemental deficit irrigation. *Int. J. Agric. Biol*., **15** : 665 -672.

Xoconostle–Cazares, B., F. A. Ramirez- Ortega, L. Flores– Elens and R. Ruiz-Medrano (2010). Drought tolerance in crop plants, *Am. J. Plant Physiol*., **5:** 241-256.