Impact of UV-B Radiation and Irrigation Frequency on Growth Performance and Tuber Yield of Different Sweet Potato (*Ipomea batatas* L.) Genotypes

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Abstract

Introduction: *Sweet potato (Ipomoea batatas L.) is an important food security crop grown at different region of Ethiopia. However, its productivity is influenced by biotic and abiotic factors including Ultraviolet B (UV-B) radiation and moisture stress. . However, the level of damage varies based on the sensitivity of plants. Therefore, the present study was designed to study the impact UV-B radiation and irrigation frequency on growth performance, physiology and tuber yield of sweet potato varieties. The experiment was conducted under greenhouse conditions, at Hawassa University during* January to May *of the year 2016 and 2017.The experiment was laid out in complete randomized design in factorial arrangement with three replications. The experiment consisted of three different factors:1) With and without UV-B radiation (0.25wm^{-2}s^{-1}); 2) three irrigation intervals (daily, every three days and every seven days) and 3) two sweet potato varieties (Aawassa-83 and Kulfo). The analysis of variance indicated that, vegetative growth, leaf water content, water use efficiency and tuber number per plant were significantly affected by combined effect of irrigation interval, UV-B radiation and variety. Extended moisture stress for three days with the involvement of UV-B radiation significantly reduced number of leaves by 30.5% (Awassa-83) and by 18.4% (Kulfo); leaf area by 49.4% (Awassa-83) and 53.6% (Kulfo) reduced stomata aperture by 3μm and tuber yield by 50% as compared to daily irrigated crops and UV-B untreated varieties. Vegetative growth and yield reduction was stronger under combined effect than moisture stress alone or UV-B radiation alone. However, Kulfo variety had maximum water use efficiency (36.26 µmol mmol^{-1}) than Awassa 83 under extended moisture stress condition.*

Key words: Awassa 83, Leaf water content, Stomata aperture, UV-B, Water use efficiency

Introduction

The climatic factors including solar radiation, precipitation and temperature are some of the abiotic components of the environmental factors that influences plant growth and development. Plants, due to their sessile nature, are potentially exposed to different environmental stresses including drought and Ultraviolet (UV) radiation. UV radiation is a part of non-ionizing region of the electromagnetic spectrum which comprises approximately 8-9 % of the total solar radiation(Kovács and Keresztes, 2002). It is divided into three wavelength ranges: UV-C (200-280 nm) which is extremely harmful to organisms, but not relevant under natural conditions of solar radiation; UV-B (280-320 nm) is of particular interest because this wavelength represent only approximately 1.5 % of the total spectrum, but can induce a variety of signaling and damaging effects in plants; UV-A (320-400 nm) represents approximately 6.3 % of the incoming solar radiation and is less hazardous parts of UV radiation (Hollósy, 2002). However, the effect varies based on the intensity, time of exposure, time of the day, angle of the sun, latitude and altitude. (Hollósy, 2002).

Under natural conditions, plants usually exposed to a number of environmental factors simultaneously, including inappropriate levels of CO2, salinity, temperature, water, heavy metals and UV radiation(Tegelberg et al., 2008). The interaction between UV-B and other environmental factors may cause various responses in plants which can be additive, synergistic, or antagonistic(Alexieva et al., 2003). Water stress or soil drought is an important restricting factor, which always occurs in agricultural activity. Water stress, in particular, has been shown either to increase or mask the UV-B radiation effects(Nikolopoulos et al., 1995; Sullivan and Teramura, 1990). Previous report by (Feng et al., 2007)indicated that limiting the availability of soil moisture during the growth period was significantly reduced the negative effect of UV-B radiation on growth and yield of plants.

The response of plants to UV-B radiation can be altered by concurrent changes in other micro-climatic factors such as photosynthetic active radiation, nutrient status and water stress(CEN and BORNMAN, 1990; Murali and Teramura, 1985; Nogués et al., 1998). Furthermore, it has been reported that the effects of UV-B radiation are masked in the presence of nutrient deficiency or drought and the exposure of plant to UV-B might partially alleviate drought stress due to changes in epidermal anatomy or wax deposition, reduction in leaf area or increases water use efficiency through stomatal limitation to carbon assimilation(Allen et al., 1998; Laakso et al., 2000; Nogués et al., 1998). Ethiopia is located near the equator and about 50 % of the total landscape is characterized as a mountainous region with elevation higher than 1500 m.a.s.l.(Chamberlin and Schmidt, 2013; Zeleke and Hurni, 2001).Thus, since UV-level depend on , the sun angle, altitude and latitude of the location ,it is found that higher intensity of UV-B radiation is expected to reach ground surface at elevation from 1000 -2500 m.a.s.l altitude and (between 3-15^{o}N and 33-48^{o}E) latitude the region where more than 96% of the world sweet potato is produced (Sullivan *et al.*, 1992). Therefore, the purpose of this study was to investigate the effect of UV-B radiation and irrigation interval and compare their effect and interaction on growth, physiology, yield and adaptive mechanism of sweet potato varieties.

Materials and Methods

Description of the study area

The experimental study was conducted under greenhouse condition for two growing season of 2016 and 2017 from January to May each year at Hawassa University, Ethiopia. The site is located 7^{0} 05' N latitude and 38^{0} 30' E of longitudes which is 275 km far from Addis Ababa, the capital city of Ethiopia. Hawassa has an altitude of 1700 m.a.s.l. with the mean annual rainfall of 900 -1100 mm. The mean annual maximum and minimum temperature is 13 ^{0}C and 27 ^{0}C respectively. The Ultra violate- B radiation at field condition is 0.25$Wm^{-2}s^{-1}$(Roro et al., 2016).

Experimental materials, treatment and design

Two sweet potato varieties (Hawassa-83 and Kulfo) were used for the experiment. The varieties were selected based on adaptability, high yield potential, diseases resistance, nutritional value and current wider distribution under farmer's production(Fekadu and Shemlis, 2017). Additionally, the description of the sweet potato varieties used for the experiment were given in the table below (Table 1).

Table 1. Description of the sweet potato varieties used for the experiment

Variety	Adaptation area (m.a.s.l)	Days to maturity (days)	Yield (t/ha) at research field	Year of release and released by
Awassa - 83	1500-2500	150-180 days	36.6 t/ha.	AwARC of SARI in 1997/98
Kulfo	1200-2200	150 days	31.5 t/ha.	AwARC of SARI in 1995

The experiment was carried out in pots arranged in greenhouse. The experiment consisted three factors: two sweet potato varieties (Hawassa-83 and Kulfo), three level of irrigation frequency (Daily, Every three days and e very seventh day interval), and two levels of UV-B radiation (with 0.25wm-2s-1 UV-B radiation and without UV-B irradation). UV-B inflorescence tube (UVB-313, Q-Panel Co., Cleveland, OH, USA) was hanged above the top of plants (0.55 m). UV-B fluorescent tubes were wrapped with 0.13 mm thick cellulose diacetate polyester (Mylar type) transparent film to cut off the shortest wavelength below 290 nm (UV-C spectral region). The UV-B treatment was applied during the light period for five hours from 11:00 to 15:00hr. Water stress and UV-B treatments were started after the plants were well established (2weeks after planting). In order to fulfill the water requirement, the irrigation frequency were arranged as: daily irrigation of 50-200ml, every three days irrigation of 600-800ml and every seven days irrigation of 1000-1200 ml per pot were applied depending on the field capacity. The amount of water to be added to the plant per pot to bring the soil in to field capacity was calculated using:

Amount of water to be added = Moisture content at FC-Actual moisture content) *pot depth (cm)*pot area (cm^2). The treatments laid out in completely randomized design (CRD) with three replications. In each pot two cuttings of sweet potato vines each having 30 cm length and four- six nodes were planted. . The Physico - chemical properties of soil such as texture, PH and organic carbon, were measured using standard laboratory procedures at Hawassa University, college of Agriculture, plant and soil analysis laboratory . Moreover, bulk density, actual moisture content and moisture content at field capacity were determined in Melka Werer research center by taking twelve representative soil samples using soil core sampler.

Table 2 Physical and chemical properties of the experimental soil

Physical and chemical properties	Values
pH	7.6
Soil texture	Sandy loam
Bulk density (gm/cm^3)	1.018
Organic matter (OM %)	5.4
Organic carbon (OC %)	3.1
Total nitrogen (%)	0.11
Moisture content at FC (v/v %)	35.5
Soil moisture content (v/v %)	29.7

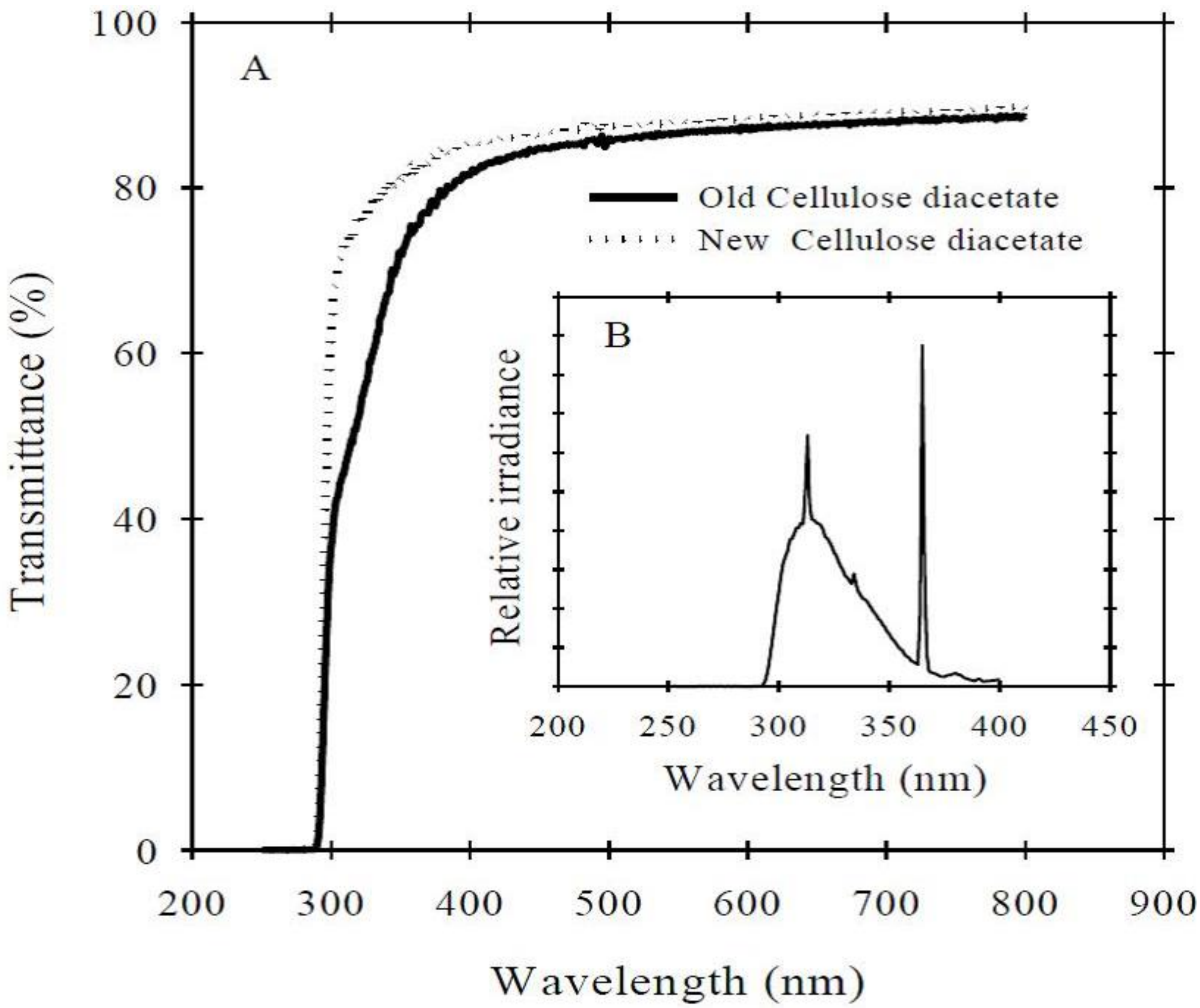

Fig 1. UV-B spectrum transmittance (%) of new (dotted line) and old (dash line) cellulose diacetate foil (A) and UV-B tube (Q-panel UV313) relative irradiance under new cellulose diacetate (B). UV treatments were delivered for 5 h centered around solar noon (11:00 - 15:00hrs). Lamps were adjusted to deliver daily exposure levels of 0.25wm2s-1.

Greenhouse Climate Condition

The daily minimum and maximum air temperatures and relative humidity for the greenhouse were recorded on randomly selected 25days using mini data loggers (Testo 174, Version 5.0.2564.18771, Lenzkirch, Germany) (Table 3). Data logger was placed inside an open bucket to avoid direct sun and hanged close to the plant canopy (30cm above the ground). The vapor pressure deficit of the greenhouse was calculated based on the temperature and relative humidity recorded using VPD-Auto grow software (www.autogrow.com/wp-content/uploads/2016/03 /VPD_HDCALC.xls). To full fill the light requirement of the crop, light intensity of approximately 350-400 umol $m^{-2}s^{-1}$, relative humidity at 70±5% and ambient CO_2 level were maintained in greenhouse.

Table 3.Greenhouse daily climatic variables recorded during the experiment (average of 25 days) (VPD is vapor pressure deficit)

Hour	Temperature (°c)	Relative humidity (%)	VPD (KPa)
1:00 pm	36.6	22.8	4.74
2:00 pm	35.7	23.2	4.49
3:00 pm	33.5	23.4	3.96
4:00 pm	31.8	24.7	3.54
5:00 pm	27.5	30.3	2.56
6:00 pm	24.3	38.1	1.88
7:00 pm	22.9	44.0	1.56
8:00 pm	21.9	47.5	1.38
9:00 pm	21.0	49.1	1.27
10:00 pm	20.1	51.4	1.14
11:00 pm	19.3	53.6	1.04
12:00 pm	18.6	56.7	0.93
1:00 am	18.0	59.2	0.84
2:00 am	17.3	61.8	0.75
3:00 am	16.6	62.7	0.70
4:00 am	16.1	64.6	0.65
5:00 am	15.6	66.3	0.60
6:00 am	15.9	66.0	0.61
7:00 am	21.7	52.6	1.23
8:00 am	27.4	40.3	2.18
9:00 am	31.3	32.5	3.08
10:00 am	33.8	27.7	3.80
11:00 am	35.0	26.5	4.13
12:00 am	36.5	24.2	4.65

Data collection

Data like vine length, leaf number and leaf area were recorded every week interval for a total of 16 weeks. However, physiological parameters were collected at vegetative growth stage (90 days after planting) Finally, yield and yield related parameters like total tuber yield was recorded at final growth stage (150 days after planting).

Data Analysis

Data collected on growth, physiology and yield parameters were subjected to the analysis of variance (ANOVA) using the SAS (statistical software). General Linear Model in SAS software were used and mean separation was made using LSD at 5% probability level of the Statistical Analysis system(SAS), version 9, 2002).

Result and Discussion

Growth parameters

The result revealed that, all growth parameters were significantly influenced by the interaction of UV-B radiation, variety and irrigation intervals ($P\leq0.05$). Result on (Fig 2) indicated that Hawassa-83 and Kulfo exposed to UV-B radiation for five hours without moisture stress significantly reduced rate of vine elongation by about 56.83% as compared to UV-B untreated plant (Fig 2A,2B and 2C). However, plant exposed to three days and seven days of moisture stress significantly reduced the rate of vine elongation by 29-30% and 10-12%, respectively. For both varieties vine growth rate was strongly affected by extension of irrigation from three to seven days' interval without the involvement of UV-B (Fig 1C). Data on Fig 1 D indicated that both genotypes treated with UV-B radiation and moisture stress inhibit vine length, but the reduction was

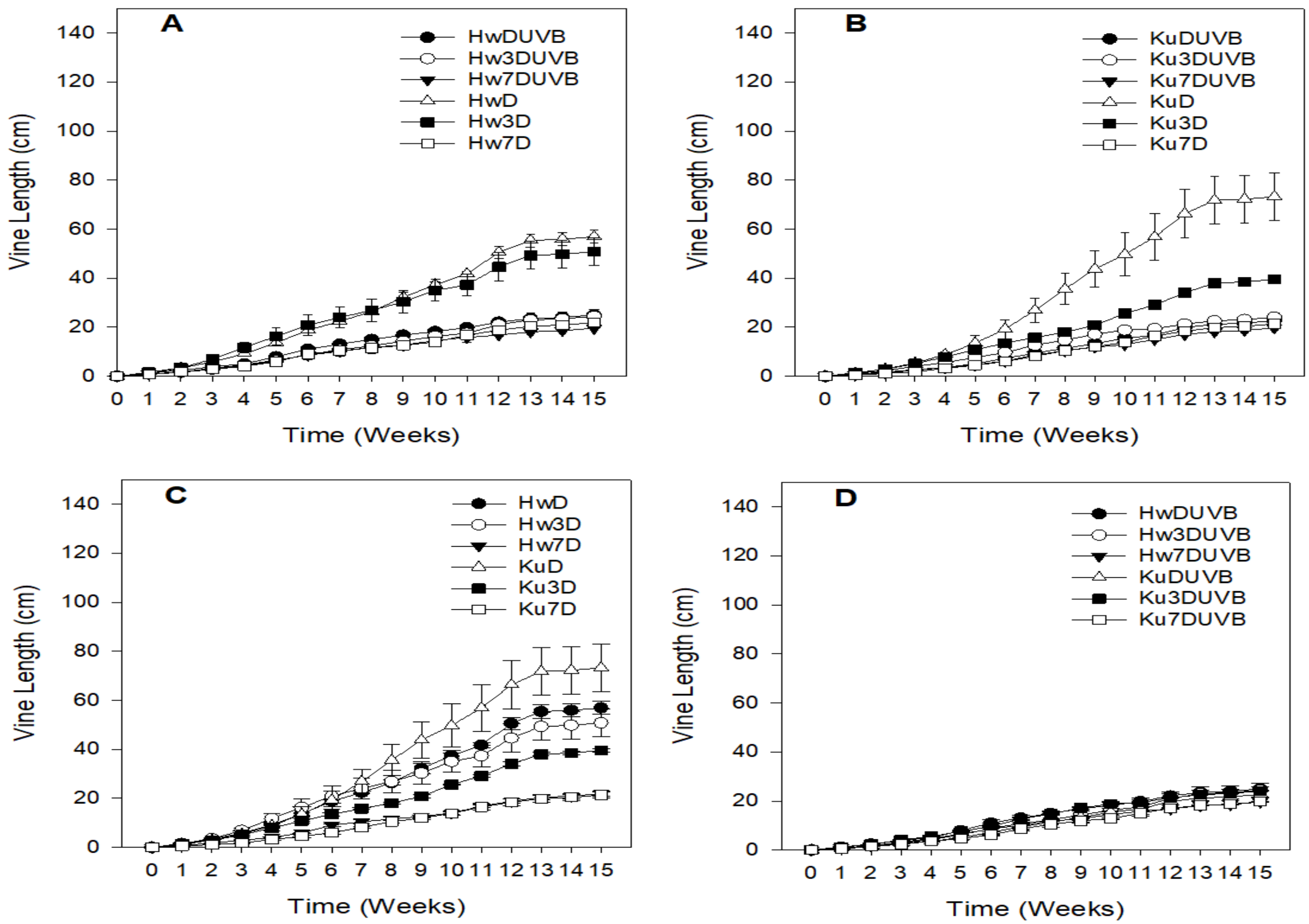

Figure 2. Impact of irrigation interval and UV-B irradiation on vine length of Hawassa-83 (A) and Kulfo (B) treated without (C) and with(D) 0.25 wm^{-2}s^{-1} UV-B radiation during the light period (11:00-15:00) under greenhouse condition. (where: HwD ,3D, 7D is Hawassa83 irrigated daily, at 3 days interval, and 7 days interval; : KuD ,3D, 7D is Kulfo irrigated daily, at 3 days interval, and 7 days interval; UVB is genotype treated with UV-B radiation)

Statistically different with in the treatments, suggesting that UV-B radiation have stronger effect in inhibiting vine length extension than effect of moisture . This might be due to moisture and UV-B radiation stress that has strong effect on growth, development and physiological performance of plants. Such reduction in growth might be related to the reduction in cell division, cell expansion and movements of stomata (Talukdar, 2013) .

Response of Leaf number, Leaf area and specific leaf area to irrigation interval and UV-B irradiation

In this study it was observed that leaf number and leaf area were significantly ($P \leq 0.05$) influenced by the interaction effects between irrigation interval, UV-B radiation and varieties. Extending the irrigation interval by three days and treating the plant with UV-B radiation for five hours significantly reduced number of leaves by 30.5% (Hawassa-83) and by 18.4% (Kulfo).Similarly, it was observed that irradiation of the varieties with UV-B for 5 hrs significantly reduced leaf area by 49.4% (Hawassa-83) and 53.6% (Kulfo) as compared to those untreated with UV-B radiation. From the result it was observed that reduction in leaf number and leaf area due to UV-B radiation was stronger on Awassa-83 than Kulfo variety. Maximum leaf area (3904 cm^2) was measured for Awassa-83 grown under daily irrigated condition without the involvement of UV-B radiation. However, with increasing the irrigation interval from daily to seven days, the expansion of leaf area did not show significant differences due to UV-B irradiation for both varieties (Table 4). Similarly, sweet potato variety irrigated daily and every three days interval significantly increased number of leaves per vine if UV-B irradiation is excluded (Table 4). The reduction in leaf number and leaf area might be related to stress induced due to UV-B irradiation and moisture stress. Pervious study reveals that plant receiving ambient levels of solar UV-B at low , intermediate, and high latitudes can inhibit stem elongation and cause reductions in leaf area expansion in various plant species(Ballaré et al., 1996; Caldwell et al., 1998). UV-B irradiation could reduce cell expansion by changing turgor pressure or cell wall extensibility, and (Zavala and Botto, 2002) suggested that direct oxidation of indole acetic acid by UV-B irradiation reduces cell wall expansion.

Physiological parameters

The relationship between plant form and environment has played a central role in plant growth , development and physiology. The assessment of plant water status under drought conditions helped to identify genotypes that have better adaptation strategy to tolerate moisture stress at different geographic location. It was observed that irrigation of the sweet potato variety every seven days' interval gave higher leaf water content than those irrigated daily (Fig 3). Extending an irrigation interval from daily to seven days with or without the involvement of UV-B irradiation significantly increased Relative leaf water content in Kulfo than Hawassa variety (fig 3). Extending irrigation interval from daily to seven days without treating plant with UV-B irradiation, did not affect the relative leaf water content in both varieties. Relative water content of leaf was strongly sensitive to UV-B irradiation than genotypes. This suggested that genotype with higher leaf water content under moisture deficit might have potential to survive to tolerate drought. Adaptation to water deficit can be defined in relation to mechanisms that control leaf water status and cell turgor(Lambers et al., 2008). Moreover, maintenance of leaf turgor is critical to the continuance of growth and gas exchange in the face of declining water availability(Cleland, 1971; FRANKS et al., 1995; Frensch and Hsiao, 1994). A genotype with the ability to minimize stress by maintaining turgid leaves and thick leaf epidermis in stressed environments will have physiological advantages , this allows turgor dependent processes such as growth and stomatal activity, and to protect and maintain the photo system complex from damage(Lafitte, 2002).

Table 4 Impact of UVB irradiance (11:00-15:00), irrigation interval and their interaction on some growth parameter of sweet potato varieties grown under green house (n=3)

Irrigation interval	*UV*	*Variety*	*No of leaf*	*Leaf Area (cm^{2})*
Daily	+UV	Awassa -83	74.67^{cd}	1242^{c}
	-UV	Awassa -83	117.07^{a}	3904^{a}
	+UV	Kulfo	66.07 ^{def}	600^{f}
	-UV	Kulfo	109.47^{ab}	905^{d}
Three days	+UV	Awassa -83	71.87 ^{cde}	1201^{c}
	-UV	Awassa -83	103.40^{b}	2373^{b}
	+UV	Kulfo	65.40 ^{def}	339^{g}
	-UV	Kulfo	80.13^{c}	730^{ef}
Seven days	+UV	Awassa -83	62.93^{ef}	824de
	-UV	Awassa -83	67.47^{def}	918^{d}
	+UV	Kulfo	58.53^{f}	218^{g}
	-UV	Kulfo	62.47^{ef}	255^{g}
P-Value		UV	<.001	<.001
		Var	<.001	<.001
		Irrign	<.001	<.001
		UV *Var	0.047	<.001
		UV* Irrign	<.001	<.001
		Var *Irrign	0.013	<.001

Means in the same column followed by the same letters are not significantly different at 5% level of significance

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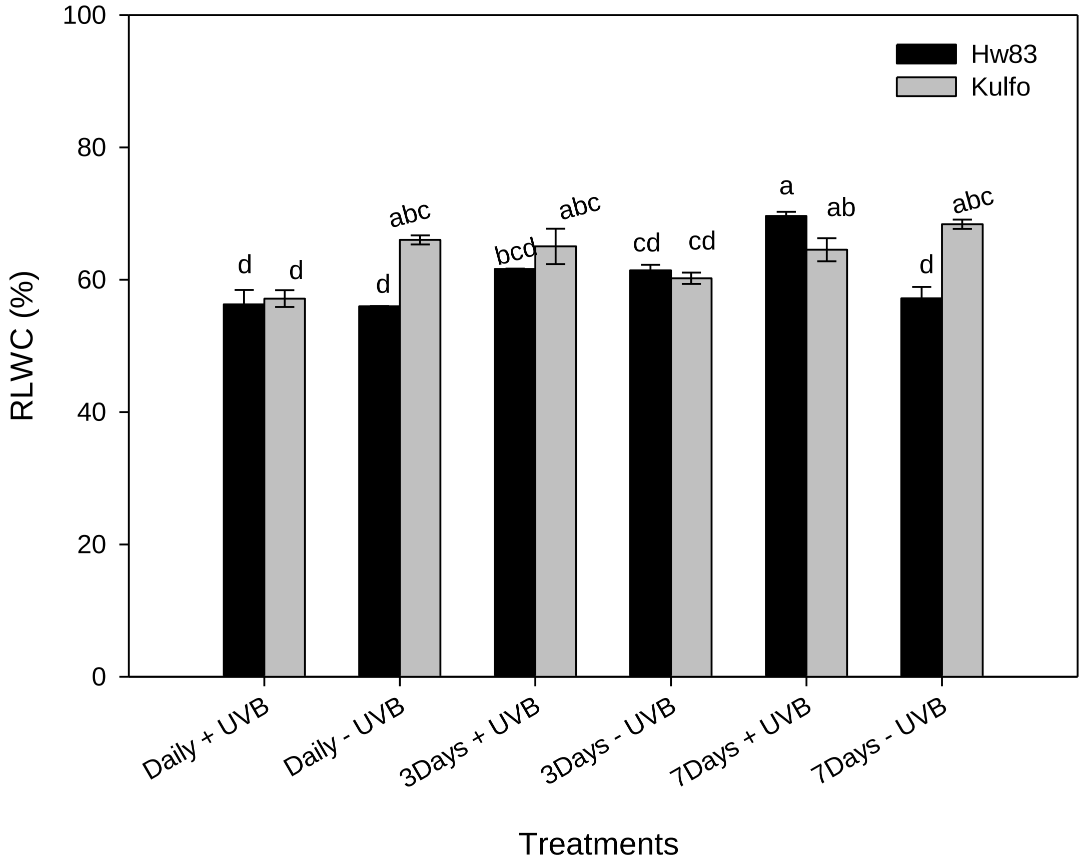


Fig 3. Relative Leaf water content(RLWC) of sweet potato varieties as affected by UV- B radiation and irrigation interval under greenhouse condition.(Bars with the same letter are not significant)

Exposing of Awassa-83 and Kulfo variety to UV-B radiation for 5 hrs. during the light period significantly reduced transpiration rate by 15.3 to 17.34 mmol m^{-2} s^{-1} and 3 to 4 mmol m^{-2} s^{-1} when each irrigation interval is combined with UV-B irradiation, respectively. Suggesting that Hawassa 83 is more sensitive to down regulate transpiration rate based on moisture level than Kulfo where UV-B irradiation is maximum.

Stomatal conductance is the measure of the rate of passage of carbon dioxide (CO_2) entering, or water vapor exiting through the stomata of a leaf. However, the rate of gas exchange can also be affected by the growth condition of the plant and genetic makeup of the plant. Previous report indicated that ,the response of stomata to environmental varies with leaf irradiance, leaf temperature, atmospheric water vapor pressure deficit and CO_2 concentration(Buckley and Mott, 2002)(Cowan, 1982)(Yoo et al., 2009). In this study two sweet potato varieties were subjected to different moisture stress level and UV-B radiation in order to evaluate the gas exchange of each variety. From the result (Table 5) it was observed that, Awassa-83 irrigated daily and grown without UV-B irradiation treatment had the maximum stomata conductance than the rest of the treatments. Irradiation of Awassa-83 and Kulfo with UV-B radiation for 5 hrs during the light period significantly ($P\leq0.05$) reduced stomata conductance of both genotypes and the effect was stronger when UV-B irradiation applied under extended moisture deficit condition. However, strong reduction in stomata conductance was observed in Hawassa 83 under UV-B irradiation than Kulfo (Table 5).

Table 5. Impact of UV-B irradiation during the light period (11:00-15:00), irrigation interval and their interaction on physiological parameters of sweet potato varieties grown under green house, (n=3)

Irrigation interval	UV	Variety	Transpiration rate (mmol m^{-2} s^{-1})	Stomata conductance (mmolm^{-2} s^{-1})
Daily	+UV	Awassa -83	9.67^{cd}	83^{ef}
	-UV	Awassa -83	24.97^{a}	187^{a}
	+UV	Kulfo	7.70^{e}	153^{bc}
	-UV	Kulfo	12.16^{b}	166^{b}
Three days	+UV	Awassa -83	8.88^{de}	93^{e}
	-UV	Awassa -83	9.58^{cd}	133^{cd}
	+UV	Kulfo	9.22^{de}	131^{d}
	-UV	Kulfo	11.09^{bc}	163^{b}
Seven days	+UV	Awassa -83	7.63^{e}	72^{fg}
	-UV	Awassa -83	11.55^{b}	86^{ef}
	+UV	Kulfo	8.02^{de}	66^{fg}
	-UV	Kulfo	7.64^{e}	60^{g}
P-Value		UV	<.001	<.001
		Var	<.001	<.001
		Irrign	<.001	<.001
		UV *Var	<.001	<.001
		UV* Irrign	<.001	<.001
		Var *Irrign	<.001	<.001
		var * Irrign * UV	<.001	<.001

Means in the same column followed by the same letters are not significantly different at 5% level of significance

Similarly, it was observed that the combination of UV-B irradiation and irrigation interval significantly influenced the rate of photosynthesis (Table 6). Although the exclusion of UV-B irradiation enhanced maximum photosynthesis rate under optimum irrigation frequency, exposing plant to three days and seven days significantly reduced photosynthesis by 0.61 µmol m^{-2} s^{-1} and 1.64 µmol m^{-2} s^{-1}, respectively. However, combining moisture stress with UV-B irradiation did not show significant influence on the rate of photosynthesis (Table 6). Such reduction might be related to the lower efficiency of photo system II and photo system I due to UV-B irradiation induced loss of integrity of the thylakoids membranes, DNA damage ,lower carbon dioxide fixation and oxygen evolution (Kataria et al., 2014). Similarly, the effect might be related to the negative effect UV-B radiation on morphological parameters and the reduction in leaf area and photosynthetic area (Dai et al., 1992)(Zhao et al., 2003).

Table 6. Impact of UV-B irradiance (11:00-15:00), irrigation interval (Irrign) and their interaction on photosynthesis rate of sweet potato varieties (Var) grown under green house (n=3)

Irrigation interval	UV-B	Photosynthesis rate (µmol m^{-2} s^{-1})
Daily	+UV-B	2.68[cd]
	- UV-B	3.91[a]
Three days	+UV-B	2.71[c]
	- UV-B	3.30[b]
Seven days	+UV-B	2.40[de]
	- UV-B	2.27[e]
P -value	UV	<.001
	Var	0.038
	Irrign	<.001
	UV *Var	0.056
	UV* Irrign	<.001
	Var *Irrign	0.021
	var * Irrign * UV	0.339

Means in the same column followed by the same letters are not significantly different at 5% level of significance.

Many studies have indicated that mild drought has no obvious impact on plant growth and photosynthesis, even stimulation to a certain degree, but severe drought can lead to dramatic reductions(Chaves et al., 2009; Fereres and Soriano, 2007; Xu and Zhou, 2006).In this study it was observed that under optimum irrigation interval the rate of photosynthesis in both genotype was not significantly different, however, extending irrigation interval from daily to seven days interval strongly reduced photosynthesis rate in Hawassa 83 variety than Kulfo (Table 7). Kulfo genotype has potential to tolerate moisture stress for three days, but extending moisture stress up to seven days significantly reduce the rate of photosynthesis by 1.09 µmol m^{-2} s^{-1} (Table7) . This result is in agreement with the work of (Kaewsuksaeng, 2011) who reported that photosynthetic rate declined linearly on different sweet potato varieties under reduced soil moisture conditions. It was suggested that stomatal closure is a key limitation for the drop in photosynthesis. Most experimental results have shown that the net photosynthetic rate (A), stomatal conductance (g_s), and mesophyll conductance (g_m) generally decrease with decreasing water availability, and an obvious reduction in photosynthesis occurs due to severe water deficit(Xu and Zhou, 2011).

Table 7. Impact of irrigation interval on photosynthesis rate of sweet potato varieties grown under greenhouse condition (n=3)

Irrigation interval	Varieties	Photosynthesis rate (µmol m^{-2} s^{-1})
Daily	Awassa-83	3.21[a]
	Kulfo	3.37[a]
Every Three day	Awassa-83	2.85[b]
	Kulfo	3.16[a]
Every Seven day	Awassa-83	2.38[c]
	Kulfo	2.28[c]
P -value	UV	<.001
	Var	0.038
	Irrign	<.001
	UV *Var	0.056
	UV* Irrign	<.001
	Var *Irrign	0.021
	var * Irrign * UV	0.339

Means in the same column followed by the same letters are not significantly different at 5% level of significance.

Water use efficiency (WUE) is one of an important physiological parameters that help to know the potential of the crop to withstand the moisture stress condition of the surrounding and help to regulate the irrigation frequency of agricultural crops. The scarcity of water resources is leading to limitation in productivity of the crop, but such problem can be alleviated by increasing crop water use efficiency, so that improving WUE of crops is becoming a main goal for agriculture and food security (Deng et al., 2006)(Medrano et al., 2015). In this study we investigated that the intrinsic water use efficiency of sweet potato varieties was significantly influenced ($P \leq 0.05$) due to the interaction between irrigation interval and UV-B radiation. Result on (Fig 4) indicate that Kulfo variety exposed to seven days of moisture stress had maximum intrinsic water use efficiency (36.26 µmol $mmol^{-1}$) as compared to other treatments with and without the involvement of UV-B radiation. Previous report indicated that genetic variability in WUE_i at different levels were associated with growth condition and the complexity of light interception, night transpiration, and respiratory losses(Medrano et al., 2015). According to (Hofmann et al., 2003)report, drought and UV-B radiation interacted synergistically resulting in a substantial increase of UV-B radiation-absorbing compounds, including phenolic (flavonols and glyco-sides), in drought-stressed plants. It was also reported that the combination of UV-B and water stress resulted in significantly increased WUEi in different cultivars(Hofmann et al., 2003).

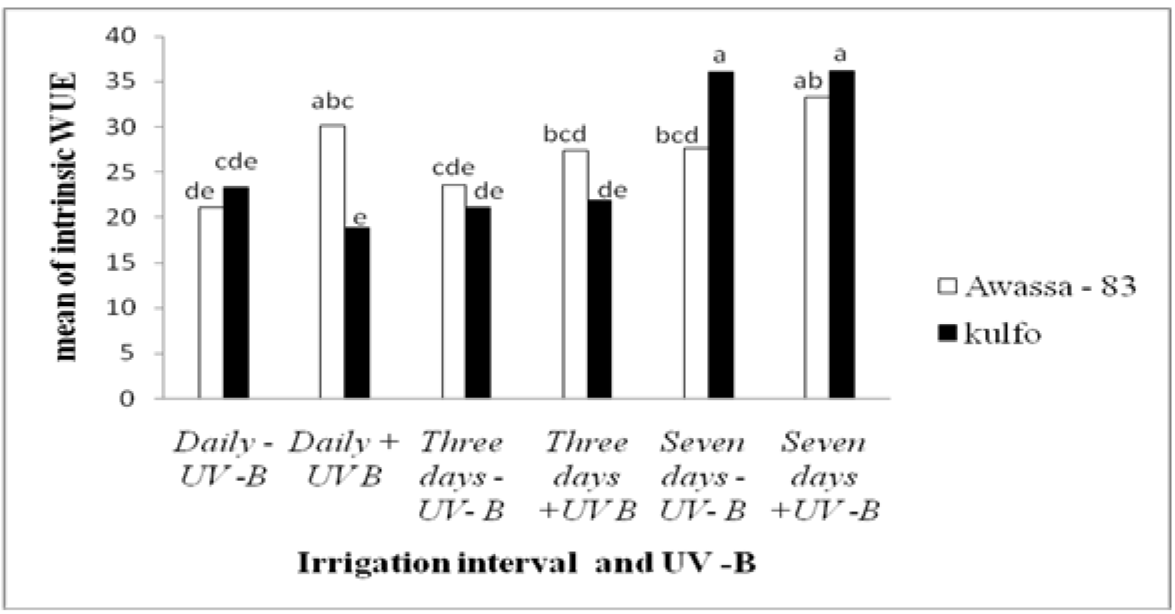


Fig 4. Effect of UV- B, irrigation interval and their interval on intrinsic water use efficiency of sweet potato varieties (Bars with the same letter are not significant different).

The analysis of variance revealed that the interaction between irrigation interval, UV-B radiation and variety did not significantly ($P>0.05$) affect stomata number and stomata aperture on each sweet potato varieties. However, stomata number and stomata aperture were significantly ($P \leq 0.05$) responded to the main factors like UV-B radiation and irrigation intervals.

Previous report indicated that Photosynthetic rate and productivity in many plant species can be reduced based on the dynamics of stomata movement and exposure time to UV-B irradiation. (Teramura and Ziska, 2006). Although, it is not clear whether changes in stomatal function play a major role in the UV-B-induced inhibition of photosynthesis, report indicated that exposure to UV-B radiation can modify the speed of stomatal opening and closing and reduce the rate of leaf transpiration (Day and Vogelmann, 1995; Middleton and Teramura, 1993; NEGASH, 1987). However, the response varies based on the genotype and growth condition. In this study it was observed that, Hawassa 83 grown without UV-B irradiation gave the widest stomata oping (22.45µm) as compared to kulfo variety (Fig 6). (Nogués et al., 1999) suggest that High-UV-B irradiances affect stomata directly, by acting on the guard cell aperture control mechanisms. Similar finding by (Dai et al., 1992) also indicated that, exposure of rice varieties (*Oryza sativa* L.) to UV- B reduced both stomata number on the adaxial surface of leaf and on stomatal opening due to extended exposure UV- B.

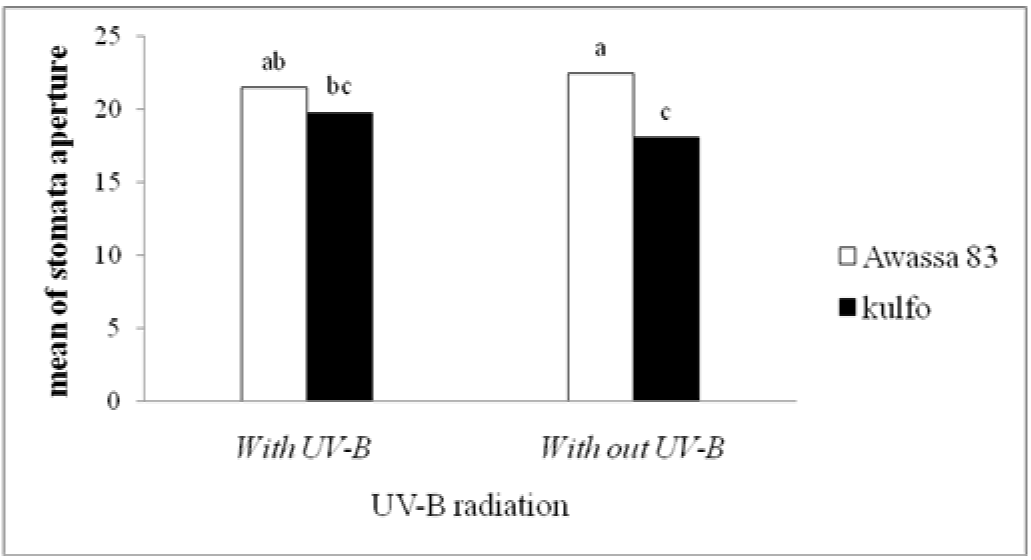
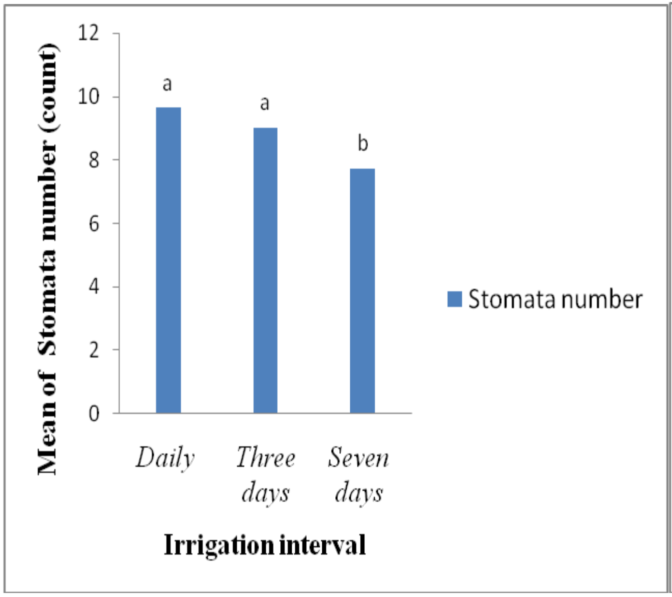


Fig 6. Stomata width as affected by UV-B radiation and variety (Bars with the same letter are not significant different)

Extended moisture stress up to seven day reduced the number of stomata by 2 per mm2 leaf area as compared to regularly irrigated sweet potato plant. Such stomata reduction in number might be related to a reduction on the size of leaves due to moisture stress. As (Jagmail et al., 1990) illustrated as water deficit reduce the amount of stomata /mm^2 reducing leaf size and to temperature stress, by increasing stomatal number. The opening and closing of stomata is driven by a number of external environmental and internal signaling cues(Araújo et al., 2011) and significant variation in sensitivity and responsiveness is known to exist among different species (Lawson, 2009;Lawson and Blatt, 2014). Similarly, plant stressed for seven days significantly ($P \leq 0.05$) reduced the stomata opening by 3µm as compared to daily irrigated crops (Figure 6). The result is in line with the result of (Jagmail et al., 1990) even if there were no variation in stomata width due to treatments but the variation comes from water deficit because it reduce leaf size and to temperature stress, by increasing stomata number(Reynolds-Henne et al., 2010).



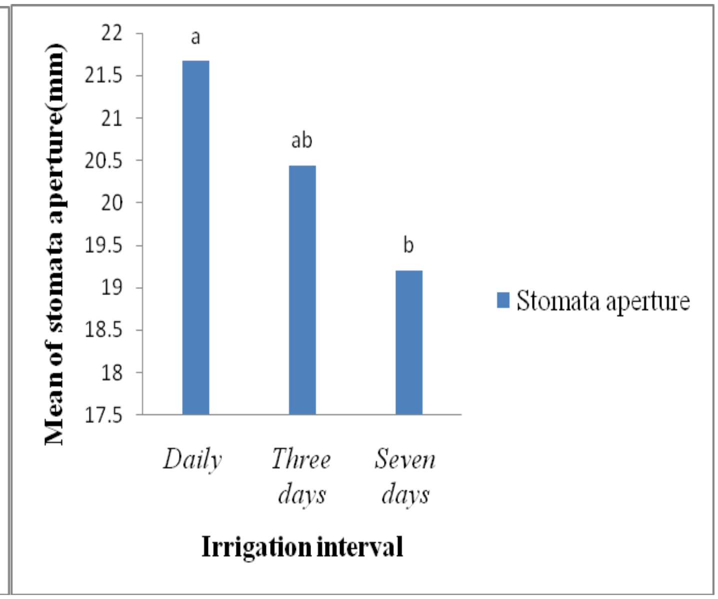


Fig 7. Stomata and aperture as affected by irrigation interval (Bar with the same letter are not statistically different)

UV-B irradiation and Moisture stress on tuber number and yield of sweet potato

At Field condition abiotic factors like soil moisture, soil and air temperature, nitrogen fertilizer and UV-B irradiation determined sweet potato yield(CHEN et al., 2020). It was observed that moisture stress combined with UV-B irradation for 5hrs significantly influenced the number of tuber, tuber fresh weight, tuber dry weight of sweet potato varaities ,. Extension of moisture stress to seven days in both varieties resulted in significant reduction of tuber number by 50% as compared to daily irrigation in both crops. However, UV-B radiation had stronger reduction effect on the number of tubers per plant than the effect of irrigation and varieties. Maximum numbers of tuber were found on Awassa-83 (5.133) when irrigated daily without the involvement of UV- B radiation for 5hrs during the light period (Fig 8). The difference in number of tubers per plant might be due to the effect of UV-B radiation that affect growth and yield through limiting the accumulation and translocation of assimilate. As previous report indicated that during the reproductive phase, leaves, stems, and other vegetative parts of the plant compete for assimilate and also influences the redistribution of assimilate within the plant organs. Moreover, it was indicated that plant exposed to UV-B decreased plant height, leaf area and dry weight, but increased axillary branching and leaf curling in spinach(Zegada-Lizarazu et al., 2012). The responses of plants to changes in UV-B also depend upon concomitant stresses, such as low and high levels of photosynthetic active radiation, temperature extremes, pollutants, metal toxicity, drought and nutrient limitation(Baud and Beck, 2005). Reduction in growth and yield due to UV-B radiation and other environmental stress on plants can be additive, synergistic or antagonistic effect(Bais et al., 2018). However, the effects of UV-B depend largely on the dose supplied and on other environmental variables encountered, such as the quality and quantity of visible and UV light and availability of nutrients (Zhao et al., 2003). This is therefore such variation in our test plant might be due to capacity difference of varieties in response to stress factors. Therefore, result of the current study is in line with the finding of(Kakani et al., 2003) who reported that, the storage root number was significantly affected by UV-B but not the storage root weight. Similarly, the reduction in tuber yield is directly related with the degradation of photosynthetic pigment and lower photosynthetic efficiency(Kataria et al., 2014). Moreover, stress due to moisture and sensitivity of genotypes to environmental stress attributed reduction the yield and total tuber produced per plant (Yooyongwech et al., 2013).

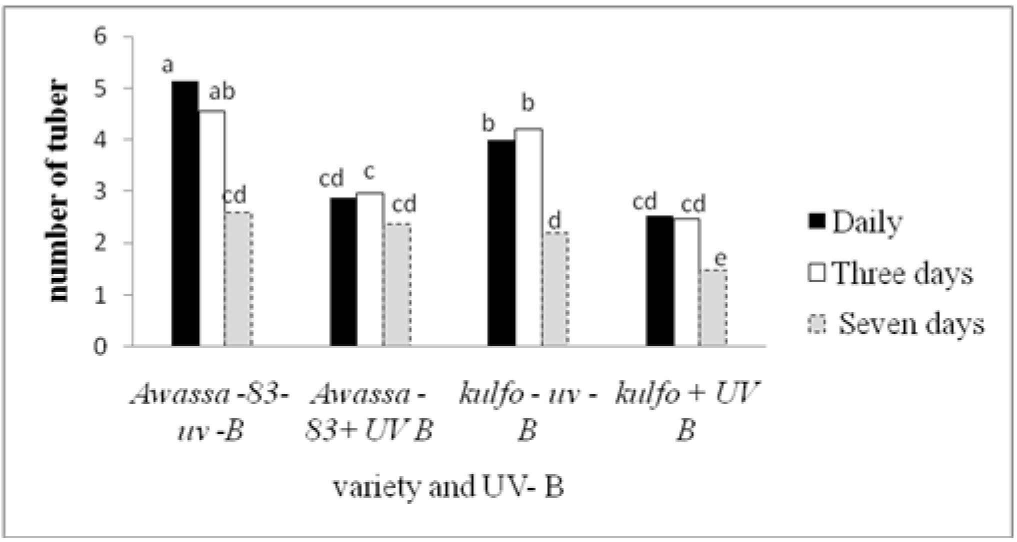


Fig .8 Effect of UV-B and irrigation on number of tuber of sweet potato varieties (bars with the same lettering are not significantly different)

The analysis of variance indicated that UV-B radiation and variety had stronger effect on Fresh and dry weight of tuber (Table 8).

Irradiation of Awassa-83 and kulfo with 0.25 Wm^{-2} S^{-1} UV-B radiation for five hours during the light period (11:00-15:00hrs) significantly reduced tuber fresh weight dry weight of tuber, fresh weight and dry weight of total biomass under daily and three days of irrigation interval. Although an extension of moisture stress for seven days strongly reduced tuber fresh weight in both varieties as compared to control, there was no significant difference between UV-B treated and UV-B untreated varieties (Table 9). In both varieties it was observed that, moisture unstressed varieties were more sensitive to reduce tuber fresh weight due to UV-B radiation and such reduction in tuber fresh weight reduced with increasing moisture stress.

In both varieties it was observed that, moisture stressed varieties were more sensitive to reduce tuber dry weight due to UV-B radiation and such reduction in tuber dry weight increased with increasing moisture stress (Table 9). The current result is supported by the result of (Kataria et al., 2014) who reported that direct effects of enhanced UV-B radiation on photosynthesis was the major cause for the reduction of dry weight per genotypes. Similarly report by (Feng et al., 2007)also indicated that ,the economical yield was inhibited due to the effect of enhanced UV-B radiation and water stress.

Table 8 Impact of UV-B radiation applied during the light period (11:00-15:00), irrigation interval and variety on yield and yield related parameters, of sweet potato varieties grown in green house. (n=3)

Irrigation interval	*UV*	*Variety*	*Tuber fresh weight (gm)*	*Tuber dry weight (gm)*
Daily	+UV	Awassa -83	212.5c	60.26[c]
	-UV	Awassa -83	292.4 a	105.04[a]
	+UV	Kulfo	96.4 fg	27.61[g]
	-UV	Kulfo	117.7e	37.03[ef]
Three days	+UV	Awassa -83	203.7c	56.56[cd]
	-UV	Awassa -83	270.9b	89.55[b]
	+UV	Kulfo	85.5g	23.23[gh]
	-UV	Kulfo	102.7f	30.64[fg]
Seven days	+UV	Awassa -83	126.1de	42.42[e]
	-UV	Awassa -83	137.4d	52.18[d]
	+UV	Kulfo	53.9h	17.51[h]
	-UV	Kulfo	63.2h	24.58[gh]
P-Value		UV	<.001	<.001
		Var	<.001	<.001
		Irrign	<.001	<.001
		UV *Var	<.001	<.001
		UV* Irrign	<.001	<.001
		Var *Irrign	<.001	<.001
		var * Irrign * UV	<.001	<.001

Means in the same column followed by the same letters are not significantly different at 5% level of significance

Similarly, total biomass yield of the sweet potato varieties (Awassa-83 and kulfo) grown under daily irrigation interval increased by 61% and 73% due to exclusion of UV-B from the growth area. Further increase in irrigation interval to three days reduced total biomass yield by 37% (Awassa-83) and 23.65 %(kulfo) under the involvement of UV-B. Extended irrigation interval to seven days did not affect biomass yield of kulfo but 15% reduction was observed for Awassa-83 grown with the involvement of UV-B (Figure 8).

The current result is in line with the work of (Feng et al., 2007) who reported that enhancing UV-B irradiation or drought stress could decrease the net photosynthetic capacity through different paths, and led to the reduction of root, stem and leaves biomass and yield, as well as changed biomass and the harvest index.

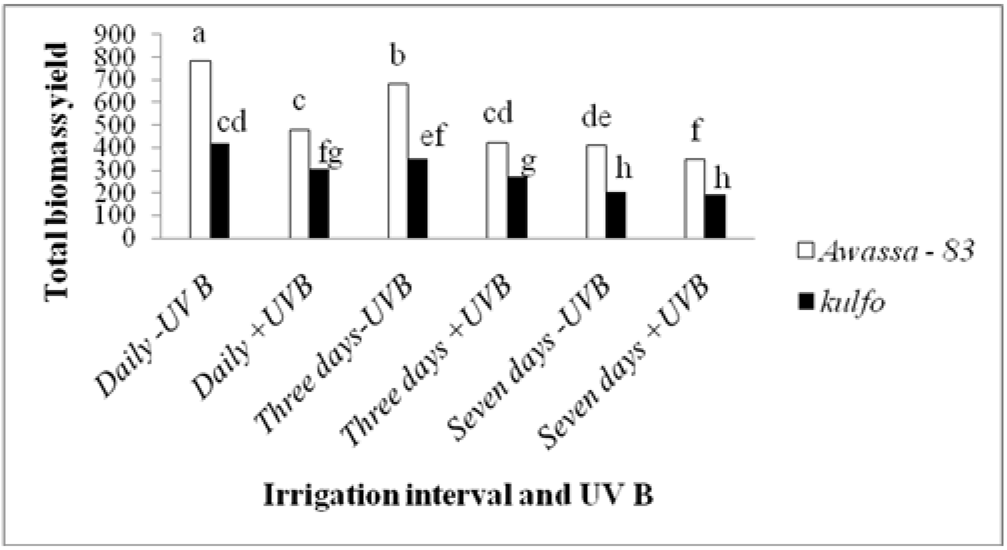


Fig 9. Total biomass yield as affected by the interaction effect of UV-B irradiance, Irrigation interval and varieties (Bars with the same letter are not significantly different)

Conclusions

This study was proposed to investigate the effect of UV-B radiation and irrigation frequency on growth performance and yield of sweet potato (*Ipomoea batatas* L.) Varieties, at Hawassa, SNNPR, Ethiopia under greenhouse condition. Extended irrigation interval in combination with UV-B irradiation slow down the rate of elongation in sweet potato vine length, but the reduction in rate of elongation was more stronger with daily irrigate variety than those irrigated every three or seven days. Exposure of sweet potato variety to UV-B radiation for five hours during the light period significantly reduces leaf area by limiting leaf emergency rate. Such reduction in leaf area and rate of leaf emergency was stronger under extended irrigation interval than daily irrigated variety.

The assessment of plant water status under drought conditions is essential for the understanding of the physiological adaptation mechanisms of plants, because water stress is one of the most common limitations of crop growth and yield. In this study it was observed that sweet potato variety subjected to seven days of moisture stress and treated with UV-B radiation for five hours contain more leaf water content than plant regularly irrigated. From the result it was observed that Awassa-83 has higher leaf water content than Kulfo variety. The increase in leaf water content under UV-B radiation stress condition could be interpreted as an increased plant protection from UV damage and reduction of water loss in the continuing drought treatment. An increase in water use efficiency in kulfo might be due to an increase in intensity of moisture stress and reduction in stomata number and stomata aperture. Moreover, plant with more Leaf water content and intrinsic water use efficiency was due to reduction in transpiration rate, Stomata conductance and reduction in stomata aperture size under extended moisture stress and UV-B irradiation. Extension of moisture stress to seven days with involvement UV-B leads to 50% reduction in tuber number per plant as compared to daily irrigation in both sweet potatoes grown without the involvement of UV-B. However, UV-B radiation had stronger effect on reduction of tuber numbers than the effect of irrigation and cultivars. Finally, it was observed that Awassa-83 and Kulfo variety significantly responded to environmental factors in terms of growth, physiology and yield. In conclusion, further studies including different sweet potato varieties, irrigation frequencies accompanied with economic analysis at field condition is suggested to give reliable recommendation and ascertain the result for sweet potato growers and other stakeholders.

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