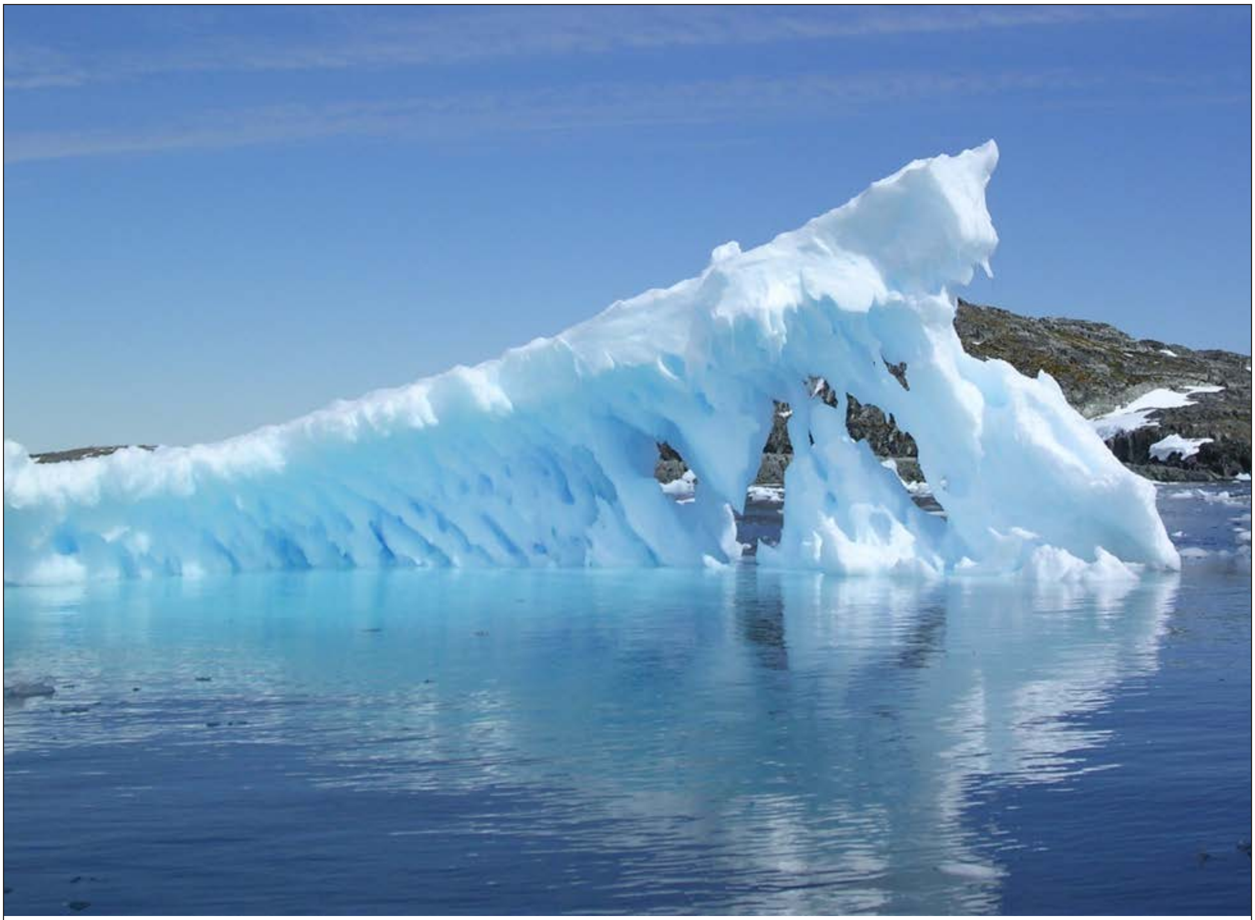

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Response of Seed Germination of Safflower to UV-B Radiation

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Abstract: Increased levels of solar ultraviolet-B (UV-B) have been measured at temperate and polar regions of the Earth surface as a consequence of decreases in the stratospheric ozone layer. Although, UV-B represents only a small part of the solar radiation reaching the earth, its impact on biological processes can be very deleterious, owing to its high energy level. Treatment of safflower (*Carthamus tinctorious*) seeds with artificial UV-B radiation caused changes in seed germination and seedling growth. In all treatments, UV light sped the germination of these seeds but the subsequent growth of the seedlings was markedly retarded. Pictures are presented to show this latter effect and the possible effects of UV-irradiation on seed germination are discussed. Therefore, continual exposure to UV-B could have similar effects on seeds. The hypocotyls become quite short and there is less above shoot biomass.

Key words: Seed germination, UV-B radiation, safflower, compositae

INTRODUCTION

The stratospheric ozone layer is the principal agent absorbing ultraviolet radiation in the Earth's atmosphere and the thinning of this layer has led to an increase in solar UV-B radiation (280-320 nm) reaching the Earth's surface. The increase in solar ultraviolet-B (UVB) radiation (280-320 nm) reaching the earth's surface, because of depletion of the stratospheric ozone layer, is a serious environmental concern (Madronich *et al*., 1995). Assuming full compliance with the montreal protocol on Substances That deplete the ozone layer United Nations Environment Program, Na. 87-6106), O_3 depletion was predicted to peak around 1998 and then slowly recover by about 2045 (WMO, 1995). However, numerous researchers have questioned the validity of the assumptions upon which these predictions are based (Allen *et al*., 1998; Greene, 1995) and have expressed concern regarding the delayed recovery of stratospheric O_3 (Shindell *et al*., 1998). The adverse effects of UVB radiation on biologically important molecules (e.g., nucleic acids, proteins, pigments and lipids), plant morphology and physiological processes have been extensively studied (Kovacs and Keresztes, 2002; Koti *et al*., 2007; Jansen *et al*., 1998; Runeckles and Krupa, 1994; Liu *et al*., 2004).When plants are exposed to UV-B radiation the enhancement of the secondary metabolite production has been detected. In fact, an increase in flavonoids and anthocyanins has been reported and it has been assumed that plants can use phytochemical defenses to avoid this harmful radiation (Ruhland and Day, 2000; Staaij *et al*., 2002). However, Pal *et al*. (1995) found no influence of UVB radiation on the germination of seeds of several crop species. plants accumulate unidentified UV-B absorbing compounds (reported as absorbance at 300 nm) after irradiation with UV-B light. In this way, plants respond to UV-B stress by synthesizing greater amounts of vacuolar metabolites which can efficiently dissipate high levels of this radiation (Xiong and Day, 2001).

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High and rapid seed germination and vigorous seedling growth are important for the establishment and competitive ability of plant species. Plant seeds on the soil surface may get exposed to solar irradiance, including biologically effective UVB radiation, before, during and immediately after germination. Although, the shoot is the primary target of UVB radiation, the radicle may be exposed to this radiation immediately after germination in the case of a seed located on the soil surface. Little information is available on seed germination and early-seedling growth response of oil-seed species to UVB radiation. In nature, plant seedlings may be exposed to an enhanced level of solar UVB radiation for a short duration and whether the damaging effect of this exposure on plant growth continues in the low-UVB environment (e.g., under cloudy conditions) that follows is not known. Safflower is one the most important oil- seed crop and despite the potential impact of UV-B radiation on field performance and therefore, on the overall productivity of this species, few studies concerning its response to this environmental stress have been done (Correia *et al*., 1998). Most of the reports describe the effects of UV-B on seedlings and individual plants grown in pots. Other developmental stages like germination, flowering and seed-set are less well documented. These stages in plant development however, might prove to be susceptible to UV-B. In a study by Musil (1995), dicotyledonous *Asteraceae* exhibited delayed flowering, decreased flower production and reduced numbers of seeds set in response to elevated UV-B. In addition, the latter study as well as several earlier studies (Flint and Caldwell, 1984; Feder and Shrier, 1990), demonstrated the UV-B sensitivity of pollen germination and pollen tube growth. It is reasonable to assume that developmental stages may have differential UV-B sensitivity, regarding that the maximal UV-B exposure of different developmental stages may vary considerably (Teramura and Sullivan, 1994).

The objectives of this study were to investigate the influence of UVB radiation on seed germination and early-seedling elongation in Safflower.

MATERIALS AND METHODS

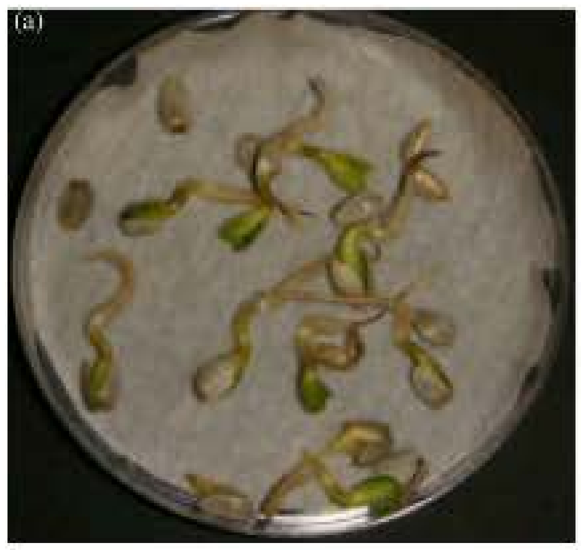
The experiment was conducted in Faculty of Science, Islamic Azad University, Mashad Branch, Iran (2008-2009). Safflower Seeds were placed on one 5.5 cm Whatman No. 1 filter disk on a 5.5 cm absorbent pad in a 6 cm open petri dish with a 5-mm-diam hole at the bottom. A completely randomized design with the three UVB treatments described previously was used. The treatments were given by exposing seeds to UVB radiation 2,4 and 8 h. UV radiation was provided by four fluorescent tubes (Philips TL 20W/12; 1220×1000 mm^2) positioned 30 cm above Petri dishes. There were four replicates per UVB treatment. Each replicate consisted of four dishes with 25 seeds per dish. To each dish was added 20 mL of distilled water. Water lost because of evaporation was replenished daily. Seed germination was periodically recorded. Seedlings with $\geq$5 mm radicle length were considered germinated. The experiment was repeated twice.

Statistical Analysis

Data reported are the Mean±SE of three independent experiments. Samples from at least four plants were taken for each replication in all measurements. Results were examined by ANOVA. Means in individual experiments were tested for significance using lower-significant-difference (LSD, $p \leq 0.05$).

RESULTS

By 22 h, 7 vs. 8 seeds had germinated in the Safflower 2 h UV-irradiated vs. control dishes. The roots were approximately 22.5 vs. 16 mm long for the controls. However, hypocotyls were 12.7 vs. 23 mm for the controls. Furthermore, the roots of the UV treated were denser and more curly (Fig. 1a, b).



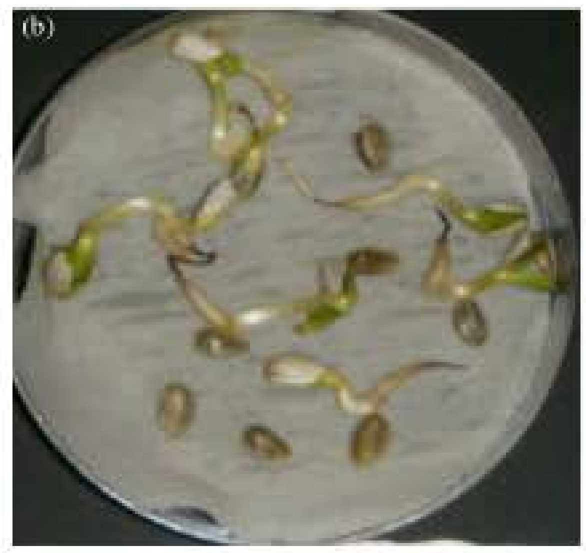


Fig. 1: Safflower (a) 2 h UV-irradiated and (b) control

Fig. 2: Safflower seeds (4 h treatment)

Fig. 3: Safflower seeds (8 h UV-irradiated)

For the 4 h treatment, 10 vs. 8 had germinated by 22 h in the UV treated vs. control groups. The roots were as long as to control (approximately 16.2 vs. 16 mm). Again hypocotyls of the UV treated were shorter than the controls(19.7 vs. 23 mmfor the controls) (Fig. 2).

The same was found for the 8 h treatment. Here, by 24 h, 9 vs. 8 seeds had germinated in the UV treated vs. control groups. Again, the roots were denser and curlier and hypocotyls were far shorter than the controls (approximately 15 vs. 23 mm) (Fig. 3).

DISCUSSION

This study shows that UV-irradiation causes more rapid germination of seeds. This is probably due to the fact that UV-B photons (280-320 nm) are more energetic than visible light photons (>400 nm) and hence, have a stronger effect on the surface of plant cells (Kovacs and Keresztes, 2002). This causes the ultimate breakdown of seed coating allowing germination to occur. Receiving 7.1 kJ/m^2/day UV-B$_{BE}$, seed germination of radish was reduced by 26%, while germination of cucumber and bean was reduced by 23% when compared with control plants receiving 0.2 kJ/m^2/day UV-B$_{BE}$ (Tevini *et al*., 1983). In contrast, Krizek (1975) observed no adverse effects on the percentage of germination for a range of crop species after 72 h of continuous exposure to UV-B irradiance. Germination of *Silene vulgaris* seeds originating from a highland and a lowland population was also unaffected by enhanced UV-B irradiance (Staaij, 1994). Musil (1995) reported enhanced germination for several dicotyledonous and monocotyledonous arid-environment ephemerals. However, once germinated the effects of continued UV-irradiation are damaging. Thus, it has been shown by Day *et al*. (2001) that exposure to UV-B reduced the vegetative growth of Antarctic vascular plants (*Colobanthus quitensis* and *Deschampsia antarctica*). This was, primarily, due to slower leaf elongation rates, which led to shorter fully expanded leaves. Krizek (1975) reported no adverse effects on dry weight accumulation of a variety of crop species after 72 h of continuous UV-B irradiance. A marked decrease of dry weight was reported by Tevini *et al*. (1983) for bean and cucumber seedlings.

In natural environments several factors may influence the maximal UV-B exposure of germinating seeds. First of all timing of germination is important. In the field, germination may occur largely in the dark, avoiding solar irradiance. Secondly, the position of the seed in the soil profile is important. Thirdly, vegetation density may markedly influence the UV-B climate at soil level. Even in the relatively sun exposed dune grassland ecosystem, germination is expected to occur at a relatively low UV-B level.

Therefore, we conclude that continual exposure to UV-B can have similar effects on seeds. The hypocotyls become quite short and there is less above shoot biomass. Hence, depletion of the ozone layer, which causes increased UV-irradiation, seems to be devastating to vegetative growth as it is to most all other cellular organisms. UV-B irradiated plants showed morphological, biochemical and genetic differences compared to non-irradiated plants. These findings support the idea that plants respond to UV-B radiation, using different strategies. The integration of molecular, chemical, physiological and biochemical information could provide some details about the actual responses to this radiation.

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