Effect of supplemental UV-B on yield, seed quality, oil content and fatty acid composition of *Brassica campestris* L. under natural field conditions

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RESEARCH ARTICLE

Abstract

Thinning of stratospheric ozone layer had been reported since last fifty years due to emission of chlorofluorocarbons, resulting in an increase in ultraviolet-B (UV-B) radiation. The present study was conducted to examine the effects of supplemental UV-B (sUV-B) radiation (+7.2 $kJ/m^2/s$) on yield and quality of seeds and oil of two cultivars of mustard, (*Brassica campestris*) L. cv. Sanjukta and Vardan. Number of pods, harvest index, test weight and oil content decreased due to sUV-B exposure in both cultivars. Seed quality was also reduced under sUV-B in terms of protein, sugar and amino acid contents. Further, quality of oil was deteriorated due to increases in erucic acid, polyunsaturated fatty acid and ω-6 fatty acid contents and reductions in oleic acid and nervonic acid contents due to sUV-B exposure. Cultivar Vardan showed more negative impact on seed yield due to UV-B stress, whereas quality of seed and oil was more affected in Sanjukta. Results of the present study confirmed the potential loss in yield as well as quality of seeds and oil of mustard under futuristic levels of increase in UV-B radiation.

Keywords: *Brassica campestris* L., fatty acid profile, oil quality, seed quality, ultraviolet-B, yield

1. Introduction

India is placed among the top few vegetable oil economies of the world. Mustard is a major oilseed crop and is grown across 53 countries of the world with India being the second largest cultivator after China (Hedge, 2005). In India, it's the second most important oilseed after ground nut sharing 27.8% in country's oil economy (Kumar, 1999). India imports about 40% of its annual edible oil needs. This demand is expected to increase in future due to significant increase in pollution and effects of climate change (Boomiraj *et al.*, 2010). Mustard is very sensitive to climatic variables and significant effects on its production is projected in near future of climate change (Boomiraj *et al.*, 2010).

The present scenarios of global climate change are predicting that elevated fluxes of UV-B radiation will be a continuing phenomenon until the middle of this century (WMO, 2007). Anthropogenically released trace gases have profound impact on ozone (O_3) concentration in the stratosphere. After the discovery of springtime O_3 hole over Antarctica in 1985 (Farman *et al.*, 1985) scientific recording of 'total ozone column' (TOC) and its future predictions have been started. Hosseinian and Gough (2000) have reported that TOC is declining at an average rate of 0.64% per year over last 38 years. In India the fertile Indogangetic plain is experiencing a significant decline of 0.8-1.5% Dobson unit per decade (Tandon and Attri, 2011). As per the report of the World Meteorological Organization (2007), the mid latitude O_3 column loss for the period of 2002-2005 was 3% in Northern hemisphere in relation to 1970s. Three dimensional chemistry climate models suggest that the current ground level of UV-B radiation is near its maximum and is expected to revert to the pre-1980s level by 2010-2070 in mid latitude, after the full implementation of Montreal protocol. In fact, the non-compliance by member countries would delay the recovery of O_3 layer and will also continue to raise the need of the studies to evaluate the deleterious effects of UV-B on plants.

Enhanced UV-B causes many direct and indirect effects on plants like stunting of growth, inhibition of photosynthesis,

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DNA damage, changes in phenology, biomass accumulation and yield (Albert *et al.*, 2010; Kakani *et al.*, 2003; Mohammed *et al.*, 2007). Negative impact of UV-B on plant growth has been well accepted, however, the effects of elevated dose on yield and quality of agricultural crops, especially oilseeds, are still not studied extensively. Some previous studies reported UV-B induced yield reduction in rice (Hidema and Kumagai, 2006), pea (Agrawal and Mishra, 2009), soybean (Yuan *et al.*, 2002) and wheat (Agrawal *et al.*, 2004; Rathore *et al.*, 2003). The effect of UV-B on yield of *Brassica rapa* was reported by Demchik and Day (1996). Changes in quality characteristics due to UV-B were also examined in few plants like soybean (Teramura, 1990), wheat (Zu *et al.*, 2004) and potato (Singh *et al.*, 2011). Gao *et al.* (2003) have reported a decline in economic value of cotton balls under UV-B exposure. An increase in protein content of rice (Zheng *et al.*, 2003) and increases in protein and amino acid contents of wheat (Zu *et al.*, 2004) have been reported under UV-B exposure. Various studies have assessed the changes in oil content and fatty acid profile of some oil crops due to environmental stresses, like heat (Besbes *et al.*, 2005), drought (Ali *et al.*, 2009), salinity (Anwar *et al.*, 2006) and O_3 (Bosac *et al.*, 1998). However, studies regarding the changes in quality of seeds and oil of oil yielding crops under UV-B stress are still in their infancy.

The present study was conducted to examine the influence of supplemental ultraviolet-B (sUV-B) radiation on yield, seed quality, oil content and oil quality of two cultivars of *Brassica campestris* L. (mustard) grown under natural field conditions.

2. Materials and methods

Experimental site and plant material

The study was conducted in the Botanical Garden of Banaras Hindu University, Varanasi (25° 14' N, 82° 03' E) located in the Eastern Gangetic plains of India between November 2010 to March 2011. During the experiment, mean maximum temperature was 33.8 °C while mean minimum temperature was 7.0 °C and mean relative humidity ranged from 33.9 to 88.5%. The total rainfall was 8.1 mm. Total sunshine hour ranged from 6.4 to 8.7 h/day (Table 1).

Mustard (*B. campestris* L.) is an important source of edible oil and a protein diet. Mustard oil contains high levels of unsaturated fatty acids (6% ω-3 fatty acid, 16% ω-6 fatty acid) and low levels of saturated fatty acids. Two widely grown cultivars of mustard, Sanjukta and Vardan, in North-eastern zone of India, were chosen for the present study and seeds were procured from the Department of Genetics and Plant Breeding, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, India.

Experimental design

Seeds of mustard were sown in twelve open plots of size 1.5×1.5 m and soil of each plot was fertilised with recommended doses of NPK (80:40:60 kg/ha). The twelve plots were divided into two treatments: control and sUV-B treated for two cultivars of mustard. For each treatment, three replicate plots were maintained. Supplemental UV-B was provided by Q-panel 313, 40 W fluorescent lamps (Q-Panel Inc., Cleveland, OH, USA) held in mobile and adjustable frames over each planted row. Three lamps (120 cm long) per bank were fitted 30 cm apart on a steel frame and suspended above the plants. In control plots UV-B tubes were covered with 0.13 mm polyester filter to absorb radiation below 320 nm, however, in UV-B treatment plots, tubes were covered with 0.13 mm cellulose diacetate filter (to absorb radiation below 280 nm). Thus, control plants received only ambient level of UV-B. Distance between the plant canopy and lamps were maintained at 30 cm by adjusting the mobile frames to provide sUV-B of 7.2 kJ/m^2/day (unweighted) that mimics 20% stratospheric ozone layer reduction at Varanasi during clear sky condition (Green *et al.* 1980). UV-B was measured under lamp at plant apices with ultraviolet intensity meter (UV P Inc., San Gabriel, CA, USA) and the readings were converted to biologically effective UV-B values by comparing with spectro power meter (Scientech, Boulder, CO, USA). Plants were irradiated for 3 h/day in the middle of the photoperiod. UV-B treatment was started from the two-three leaved stage of plants and continued until maturity.

Table 1. Metrological conditions at the study site during experimental period.

Month	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	Sunshine (h)
	Max	Min	Max	Min		
November 2010	30.10	17.16	87.8	70.4	0.0	7.04
December 2010	25.37	9.20	88	66.3	0.0	6.98
January 2011	21.48	7.0	88.5	64.1	3.2	6.47
February 2011	27.26	11.37	84.5	51.7	4.6	7.83
March 2011	33.80	16.22	63	33.9	0.3	8.72

Plant sampling and analysis

Yield parameters

Plants were harvested at maturity to assess various yield attributes. Ten plants were harvested from each replicate plot to quantify the weight of pods/plant, weight of seeds/plant, test weight (1000 seeds weight) and harvest index (HI; ratio of economical yield and biological yield).

Seed quality measurement

After quantitative analysis of yield parameters, seeds were analysed for qualitative characteristics like protein, total soluble sugars, free amino acids and oil contents. Protein content was measured by the method of Lowry *et al.* (1951). Total amino acids were estimated by the methodology given by Moore and Stein (1948). The method consists of extraction of amino acids in 80% ethanol and its colorimetric estimation using ninhydrin reagent at wavelength of 570 nm. Total soluble sugar was determined by using the method of Dubois *et al.* (1956). Seeds (10 g) were crushed and oil was extracted in petroleum ether by Soxhlet extraction method of Chopra and Kanwar (1991).

Oil quality and fatty acid profile

Fatty acid profile of the extracted oil was carried out by the method of the Bureau of Indian Standards (BIS, 1976): 548-(P-III)-(1976).

Statistical analysis

Significantly different means between control and its respective sUV-B treated plants were calculated using the student's t-test. Data of yield and quality parameters were analysed through two-way ANOVA for assessing the significance of changes due to treatments and cultivars. Pearson's correlation test was used to explore the correlations among changes in various fatty acids. All the statistical tests were performed using SPSS software (version 16.0; IBM, Armonk, NY, USA).

3. Results

Yield parameters

In the present study, sUV-B negatively affected all the yield attributes of both cultivars. Weight of pods/plant and weight of seeds/plant showed reductions of 42.2 and 59.7% in sUV-B treated plants of Vardan (Figure 1). Reductions of

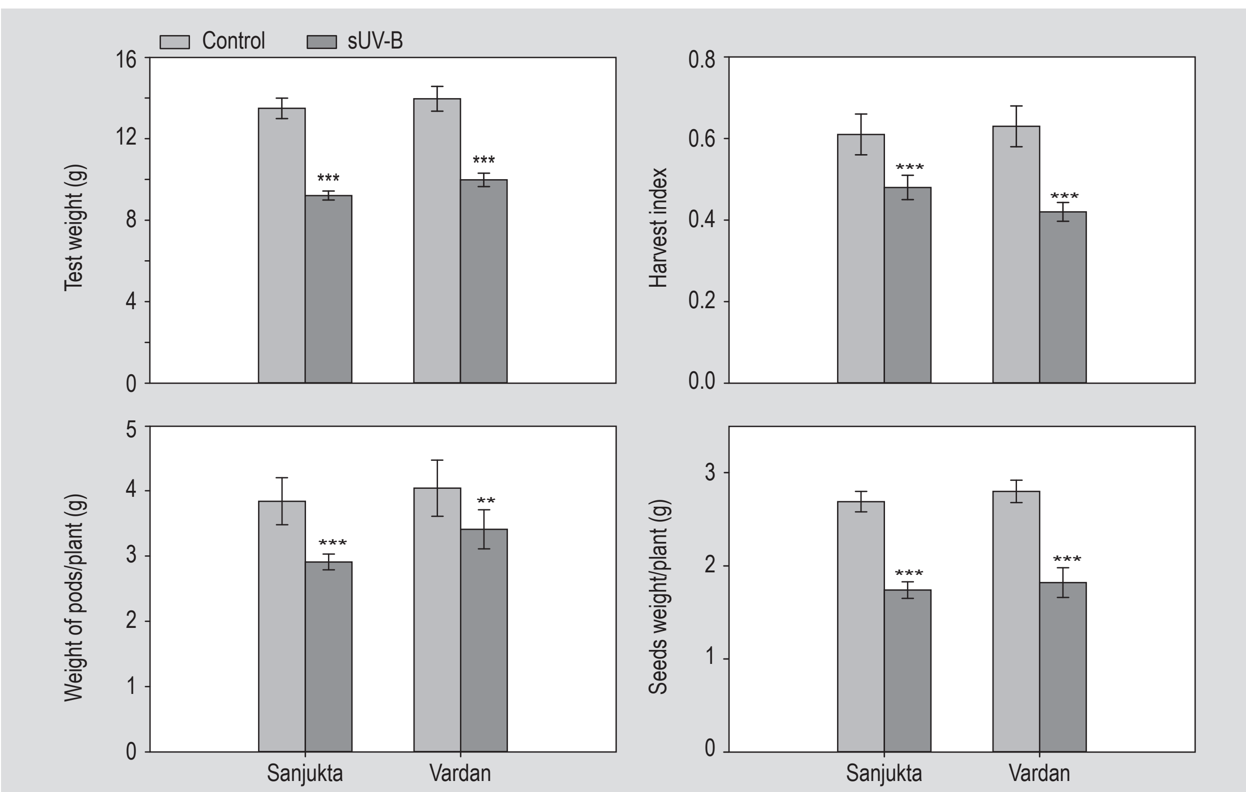

Figure 1. Changes in yield characteristics of two cultivars (Sanjukta and Vardan) of mustard under supplemental UV-B (sUV-B) exposure as compared to the control (P≤0.01, ***P≤0.001).**

30.9 and 20.2% in harvest index and 32.2 and 39.2% in test weight were observed in Vardan and Sanjukta, respectively, after sUV-B exposure (Figure 1). Multivariate analyses of yield parameters showed that individual response of sUV-B (T) was significant for all the yield parameters but individual response of cultivar (C) was significant only for test weight ($P<0.05$). Interactive response of C×T was not significant for any of the yield parameters (Table 1).

Oil content and seed quality parameters

Oil content reduced after sUV-B treatment by 38.3% in Sanjukta and 26.9% in Vardan (Figure 2). Significant reductions were also recorded in total sugars, amino acids and protein contents of mustard seeds due to sUV-B. Protein content reduced by 32.9% in Sanjukta and 31.5% in Vardan upon sUV-B treatment. Total soluble sugar showed maximum reduction of 36.7% in Sanjukta while total amino acid content showed maximum reduction of 26.3% in Vardan (Figure 2). Two-way ANOVA test showed that variations in oil content and seed quality parameters except total sugar were significant due to UV-B treatment. Individual response of cultivar and its interaction with UV-B was significant only for oil content (Table 2).

Table 2. *F*-value and significance level of yield and seed quality parameters.

Parameters	Cultivar (C)	Treatment (T)	C×T
Weight of pods/plant	3.4	24.2***	0.52
Weight of seeds/plant	1.8	186.2***	0.04
Test weight	5.9*	262.6***	0.35
Harvest index	0.75	53.9***	2.99
Oil content	21.36**	596.7***	35.3***
Total amino acids	1.02	513.1***	1.23
Total sugar	0.10	3.48	0.003
Protein content	1.43	292.8***	1.4

*$P<0.05$; **$P<0.01$; ***$P<0.001$.

Fatty acid profile

Exposure of sUV-B significantly altered the fatty acid profile of mustard oil. Oleic acid, linolenic acid and erucic acid contents were enhanced by UV-B exposure, while rest of the constituents were reduced (Figure 3). Stearic acid, linoleic acid and nervonic acid contents showed maximum

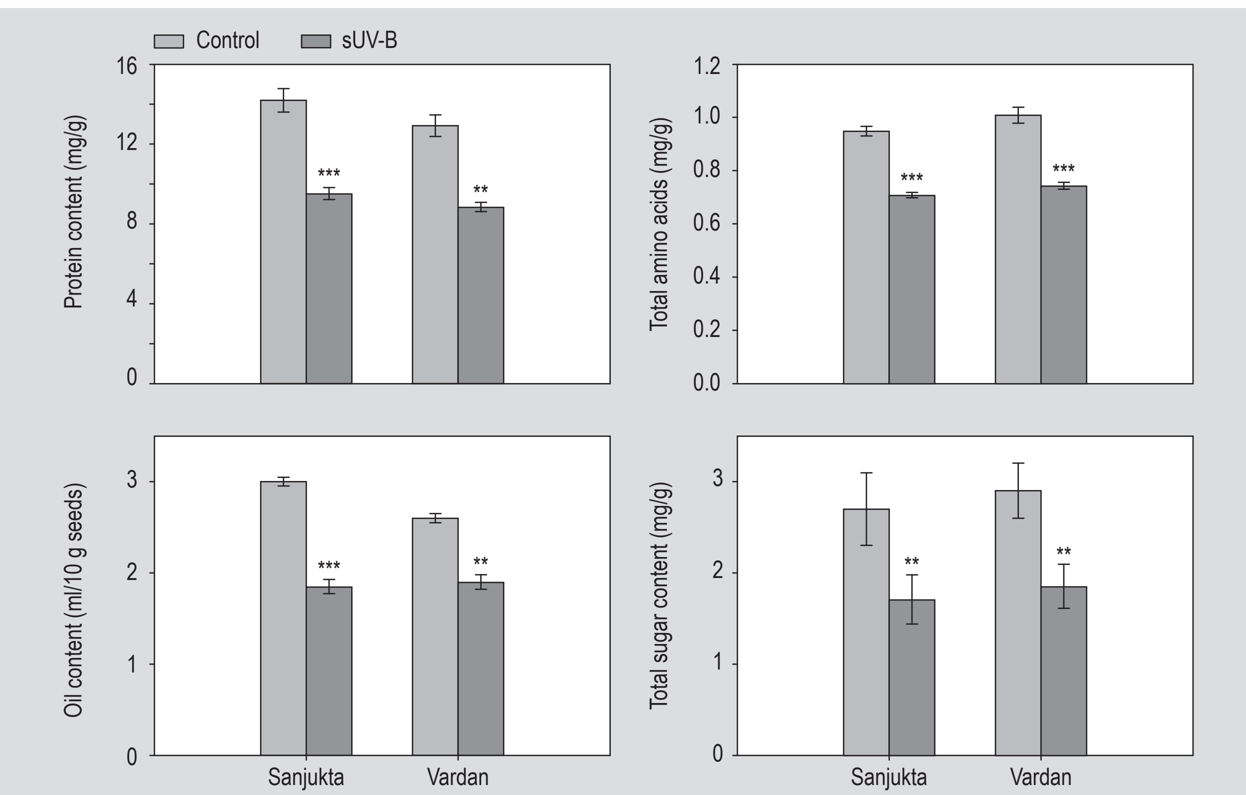

Figure 2. Changes in oil content and seed quality characteristics of two cultivars (Sanjukta and Vardan) of mustard under supplemental UV-B exposure as compared to the control (mean ± standard error; n=9; ***P≤0.01, ****P≤0.001).

reductions of 31.5, 3.1 and 30.4%, respectively, in Sanjukta, while palmitic acid showed maximum reduction of 30.2% in Vardan. Oleic acid and erucic acid contents showed increments of 15.6 and 6.5% in Sanjukta and 11.1 and 4.5% in Vardan (Figure 3). Linolenic acid showed maximum increment of 16.2% in Vardan. Multivariate analysis of fatty acid profile showed that individual response of sUV-B treatment was significant for all the fatty acids except linoleic acid, ecosenoic acid and erucic acid, cultivar (C) response was significant only for stearic acid and ecosenoic acid, whereas interactive response (C×T) was significant for stearic acid, linolenic acid and nervonic acid (Table 3).

Due to sUV-B treatment, omega-3 fatty acid and saturated fatty acids (SFA) were reduced, while ω-6 fatty acid, monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) were enhanced (Figure 4). ω-3 fatty acid and SFA showed significant reductions of 6.5 and 29.8%, respectively, after sUV-B exposure in Vardan. ω-6 fatty acid and PUFA showed maximum increments of 18.1 and 4.8% in Vardan, whereas MUFA enhanced by 6.5% in Sanjukta (Figure 4). Variations in all the parameters were significant due to sUV-B treatment and non-significant for cultivars except PUFA. However interactive response was significant only for ω-6 fatty acid (Table 3).

Table 3. *F*-value and significance level of oil quality and fatty acid profile of mustard oil.

Parameters	Cultivar (C)	Treatment (T)	T×C
Palmitic acid	3.72	52.5***	1.55
Stearic acid	11.01*	57.6***	11.01*
Oleic acid	0.31	72.2***	2.08
Linoleic acid	0.073	2.2	0.025
Linolenic acid	4.83	37.8***	34.12***
Ecosenoic acid	29.3**	0.28	0.003
Erucic acid	0.108	4.2	1.93
Nervonic acid	0.831	27.5***	7.16*
ω-3 fatty acid	1.54	11.2*	3.1
ω-6 fatty acid	2.66	57.7***	52.68***
SFA	3.73	112.25***	0.71
MUFA	1.48	13.9**	0.75
PUFA	16.3**	30.56***	1.023

*P<0.05; **P<0.01; ***P<0.001.

4. Discussion

The present study is the first report on seed and oil quality deterioration of an important oil yielding crop *B. campestris* due to exposure of sUV-B under natural field conditions. Members of *Brassicaceae* have been reported to be sensitive towards UV-B exposure (Wilson and Greenberg, 1993).

In the present study, sUV-B affected all the yield components of both the cultivars. Three major components decide the yield of a crop plant: (1) number of pods/plant; (2) number of seeds/pod; and (3) individual seed weight. In fact, number of pods/plant, number of seeds/pod and number of fertile pods are decided during the period of reproductive development after few days of anthesis. The whole phenomenon is dependent on availability of assimilate and competition between the developing pod and other sinks like stress repair processes. Hay and

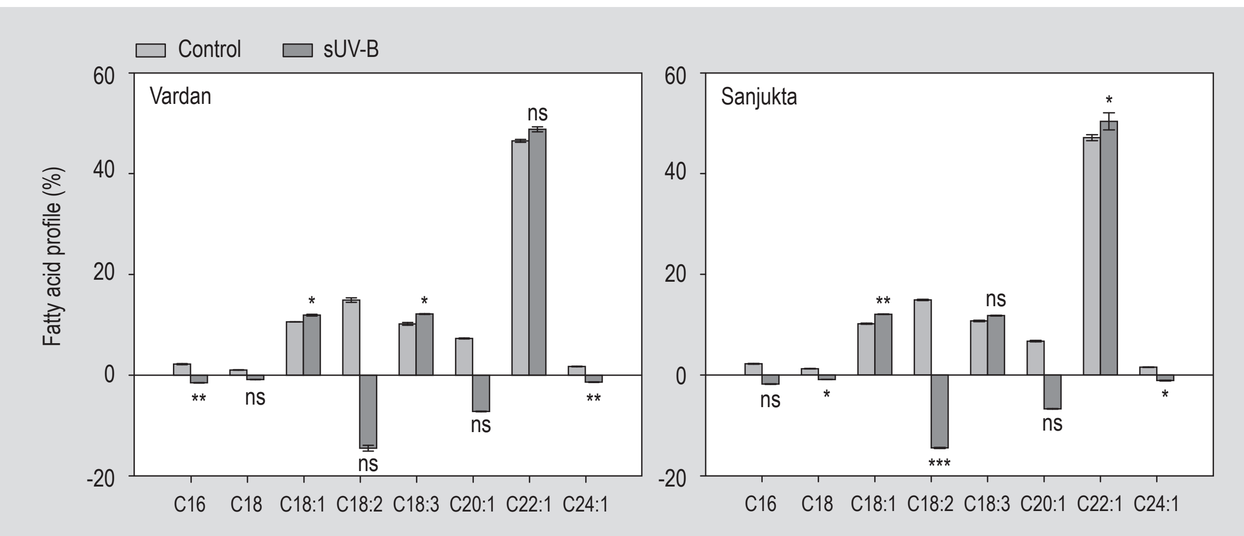

Figure 3 Changes in fatty acid profile of two cultivars (Sanjukta and Vardan) of mustard under supplemental UV-B (sUV-B) exposure as compared to the control (mean ± standard error; n=9). *P≤0.50, **P≤0.01, ***P≤0.001; ns = not significant; C16 = palmitic acid; C18 = stearic acid; C18:1 = oleic acid; C18:2 = linoleic acid; C18:3 = linolenic acid; C20:1 = ecosenoic acid; C22:1 = erucic acid; C24:1 = nervonic acid.

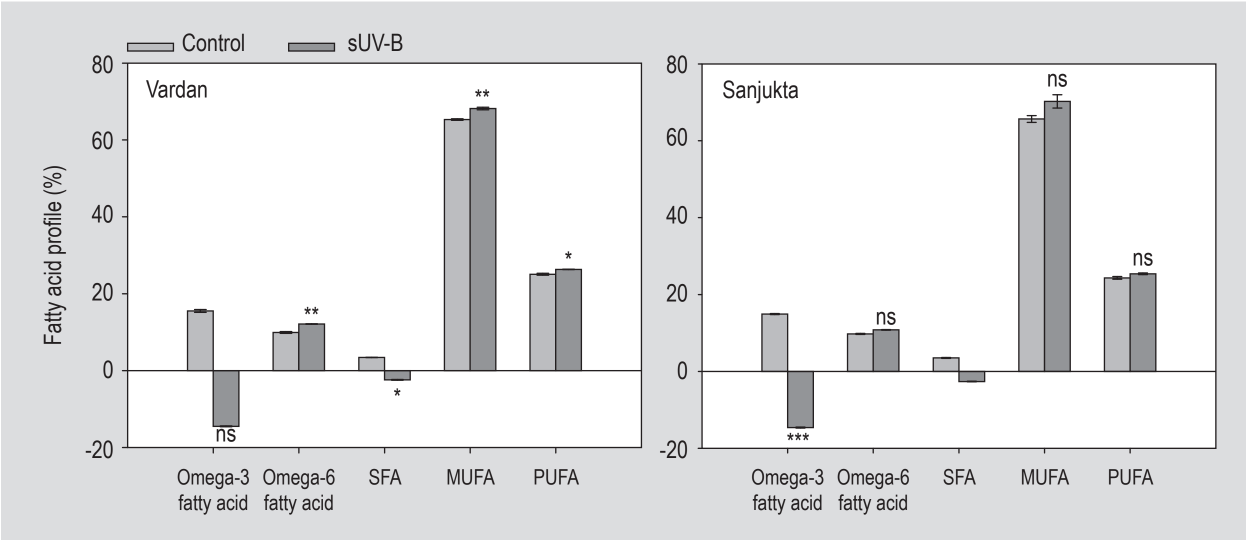

Figure 4. Alteration in fatty acid profile of mustard (ω-3, ω-6, saturated (SFA), monounsaturated (MUFA) and polyunsaturated (PUFA) fatty acids) after supplemental UV-B (sUV-B) treatments (mean ± standard deviation; n=9; $^*P\leq0.50$, $^{**}P\leq0.01$, $^{***}P\leq0.001$; ns = not significant).

Walker (1989) suggested that in crop plants one of the main deciding factors of seed yield is source-limitation. Availability of assimilates during pod filling largely depends on photosynthetic area of leaves after anthesis, pod photosynthesis and source and sink relationship. Since UV-B is well known to alter leaf area as well as process of photosynthesis and induce more utilisation of photosynthate for stress repair, exposure to sUV-B thus affected the processes of pod filling and development during the present study. Reduction in harvest index further indicates greater partitioning of photosynthates to vegetative portion and lesser amount to reproductive parts to develop seeds. Correia *et al.* (1998) and Feng *et al.* (2007) also reported reductions in HI after UV-B exposure of wheat and maize plants, respectively. Agrawal *et al.* (2006) reported reduction in HI due to change in dry matter allocation to different parts of *Vigna radiata* under enhanced UV-B exposure. Due to sUV-B exposure, number of pods and seeds reduced more in Vardan, while test weight was reduced more in Sanjukta. This finding clearly suggests that size of seeds was more negatively affected in Sanjukta. Likewise, Hidema and Kumagai (2006) reported reductions in size as well as yield of rice grains under UV-B exposure.

Reductions in total sugar, total amino acids and protein contents in seeds were found under UV-B exposure. The deposition of reserve materials in seeds directly depends on photosynthesis and nitrogen assimilation in source tissue and their transport to the sink (Lohaus and Moellers, 2000). Transport of sucrose and amino acids from source to sink organs takes place via phloem tissue and it affects the relative content of protein and carbon in the seeds (Reggiani *et al.*, 1985). In mustard, protein is stored in modified vacuoles called protein bodies. Reductions in protein, total sugar and total amino acid contents in the present study might be due to impaired photosynthesis, phloem transport and competition of sinks due to stress repair processes. Prolonged investment of photosynthate mainly in UV-B induced repair processes affects growth, reproductive development and yield of plants (Feldheim and Conner, 1996). Previous studies have reported an enhancement in protein content after UV-B exposure in rice (Xu and Qiu, 2007) and no effect in wheat (Lizana *et al.*, 2009). Kumagai *et al.* (2001) have suggested that reduction in grain size resulted a change in protein content. In the present study, more reduction in protein content of Sanjukta was correlated with more reduction in individual seed weight compared to Vardan. Unlike the reduction in total sugar content in the present study, Xu and Qiu (2007) reported an enhancement in amylose content in rice grains. However, Singh *et al.* (2011) reported reduction in starch content of potato tubers under UV-B exposure. Amino acid is very susceptible to environmental stress and alteration in even one amino acid alters the whole protein. UV-B is known to affect the synthesis of amino acid and protein as well as their precursors (Teramura, 1983). Contrary to the results of the present study, Zu *et al.* (2004) reported an increase in amino acid content of wheat grains after UV-B treatment.

Mature seeds of rapeseed contain 45-50% (w/w) oil, which is stored in special oil bodies within the cytoplasm of cotyledon cells in the form of triglycerols (Nesi *et al.* 2008). The present study found a significant decline in oil content after sUV-B exposure. Reduction in oil content was also reported with other abiotic stress factors like salinity (Flagella *et al.*, 2004) and temperature (Dybing and Zimmerman, 1966). Various stress induced changes in the availability of precursors required for seed filling, altered growth of embryo and ratio of pericarp and embryo may be the responsible factor for low oil content (Dybing and Zimmerman, 1966). Reduction of 55% in seed oil content of *B. napus* was reported under elevated dose of O_3 (Bosac *et al.*, 1998).

Indian mustard oil is mainly characterised with high level of erucic acid and low level of oleic acid. However low level of erucic acid and high level of oleic acid in oil is ideal for edible purpose (Kaushik and Agnihotri, 2000). In the present study, significant negative correlations between sUV-B treatment and palmitic acid, stearic acid, linoleic acid, ecosenoic acid and nervonic acid, while significant positive correlations with oleic acid, linolenic acid and erucic acid were found (Table 4). Unlike the present report, Ali *et al.* (2009) found an increase in SFA (palmitic and stearic acid), while Baldini *et al.* (2002) didn't found any significant effect on SFA in water stressed sunflower plants. Linolenic acid is mainly synthesised from desaturation of oleic acid to linoleic acid and its further desaturation to linolenic acid (Baux *et al.*, 2008). Enzymes of these two processes are sensitive to environmental stresses. In the present study, sUV-B significantly enhanced the contents of oleic acid (r=0.88, $P<0.01$) and linolenic acid (r=0.96, $P<0.01$) indicating that sUV-B might have definitely affected the enzymes responsible for desaturation of oleic acid to linoleic acid. However, enhancement in linolenic acid suggests no effect of sUV-B on desaturation of linoleic acid to linolenic acid. Correlation between oleic acid, linoleic acid (r=-0.59, $P>0.05$) and linolenic acid (r=0.588, $P>0.05$) confirmed the results, though the response was non-significant (Table 4). Similarly, Baldini *et al.* (2002) have also reported an increase in oleic acid content under water stress due to effects on the activity of oleic desaturase. Erucic acid having an adverse effect on human health, increased in the present study after sUV-B treatment. High content of erucic acid is known to cause growth retardation, lowers the respiratory capacity of heart mitochondria (Borg, 1975; Goswami *et al.*, 2011) and increases the industrial value of oil (Wang *et al.*, 2010). It also affects beneficial function of linoleic and linolenic acid (Mortuza *et al.*, 2006). On the other hand, nervonic acid, which is a beneficial fatty acid was decreased significantly due to sUV-B. Nervonic acid has its promising role in treatment of Parkinson disease and multiple sclerosis.

Conventional double-low rapeseed oil contains a low content of SFA (5-7%) and high content of PUFA with linolenic acid (7-10%) and linoleic acid (17-21%) (Baux *et al.* 2008). However, high content of PUFA reduces the oxidative stability of oil, which is not suitable for deep frying purposes. The enhancements in MUFA, PUFA and ω-6 fatty acids, vis-a-vis decrease of SFA and ω-3 fatty acids were found. Previous studies reported that drought and heat stress lead to an increase in PUFA in leaf cells to provide resistance against the stress (Zhang *et al.*, 2005). Baux *et al.* (2008) predicted that stress conditions during seed filling

Table 4. Correlation coefficient (r) between various measured parameters of oil quality and sUV-B treatment in mustard cultivars.

	Palmitic acid	Stearic acid	Oleic acid	Linoleic acid	Linolenic acid	Ecosenoic acid	Erucic acid	Nervonic acid
Sanjukta								
sUV-B	-0.928**	0.972***	0.99***	-0.688	0.146	-0.148	0.670	0.942***
Palmitic acid		0.988***	-0.889*	0.688	0.018	0.344	-0.684	0.978***
Stearic acid			-0.944**	0.702	-0.38	0.277	-0.673	0.984***
Oleic acid				-0.590	0.279	-0.009	0.725	-0.926**
Linoleic acid					0.588	0.754	-0.29	0.585
Linolenic acid						0.940**	0.641	-0.132
Ecosenoic acid							0.344	0.184
Erucic acid								-0.724
Vardan								
sUV-B	-0.936**	-0.818*	0.88*	-0.397	0.96**	-0.239	0.473	-0.672
Palmitic acid		0.713	-0.688	0.391	0.937***	0.562	-0.228	0.381
Stearic acid			-0.773	0.25	-0.698	0.108	-0.355	0.542
Oleic acid				-0.219	0.779	0.236	0.727	-0.928**
Linoleic acid					-0.601	0.222	-0.210	0.166
Linolenic acid						-0.337	0.420	-0.579
Ecosenoic acid							0.499	-0.548
Erucic acid								-0.796

*$P<0.05$; **$P<0.01$; ***$P<0.001$.

and oil production could have the same consequences on seed oil with high amount of PUFA. However, increase in MUFA and SFA contents made the oil beneficial for human consumption, because of the positive role of MUFA in reducing the level of LDL cholesterol in blood and thus the risk of coronary heart disease (Grundy, 1986; Gunstone, 2004). Both ω-3 and ω-6 fatty acids are essential for normal growth and development and may play an important role in preventing some coronary artery disease and autoimmune disorders (Simpolous *et al.*, 1991), but increase in level of ω-6 fatty acid may promote the chances of ulcerative colitis (Castle and Gooder, 2010). Reduction in ω-3 fatty acid and enhancement in ω-6 fatty acids of mustard oil after sUV-B exposure have deteriorated the quality of oil.

5. Conclusions

The present study has shown that yield and quality of seeds as well as oil of mustard were adversely affected by sUV-B exposure under natural field conditions. Results confirmed the sensitivity of both the cultivars against sUV-B radiation. Yield parameters were more affected due to sUV-B in Vardan, whereas quality of seeds and oil were more adversely affected in Sanjukta. Results also confirmed deterioration in the quality of oil due to increase in erucic acid, PUFA, ω-6 fatty acid and reduction in oleic acid and nervonic acid contents. Mustard oil is a commercial product and oil free cakes are important component of mustard meal. The reductions recorded in quantity as well as quality of seeds and oil due to UV-B radiation would pose a serious threat for agriculturists considering the future climate change scenarios.

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Conflict of interest

The authors have no conflict of interest to declare.

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