Ecotoxicology and Environmental Safety 74 (2011) 897–903

Contents lists available at ScienceDirect

Ecotoxicology and Environmental Safety

journal homepage: www.elsevier.com/locate/ecoenv

Modification in growth, biomass and yield of radish under supplemental UV-B at different NPK levels

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ARTICLE INFO

Article history:
Received 1 July 2010
Received in revised form
18 December 2010
Accepted 20 December 2010
Available online 19 January 2011

Keywords:
Radish
Supplemental UV-B
NPK
Growth
Biomass
Yield

ABSTRACT

Growth, biomass, yield and quality characteristics of radish (*Raphanus sativus* L. var. Pusa Himani) were investigated under supplemental UV-B (sUV-B; 280–320 nm; +7.2 kJ m^{-2} d^{-1}) radiation at varying levels of soil NPK. Combinations of NPK were recommended, 1.5 times NPK, 1.5 times N and 1.5 times K. sUV-B radiation negatively affected the growth and economic yield with more reductions at 1.5 times recommended NPK, N and K compared to recommended NPK. Total biomass remained unaffected in plants at recommended NPK under sUV-B radiation. At 1.5 times NPK and N more partitioning of biomass to shoot led to reduction in root shoot ratio and consequently yield under sUV-B. Nutrients in edible part declined maximally at 1.5 times recommended K under sUV-B. The study suggests that higher than recommended NPK makes radish plants more sensitive to sUV-B in terms of yield by allocating less photosynthates towards roots compared to shoots.

1. Introduction

The stratospheric ozone (O_3) layer absorbs ultraviolet-B (UV-B) radiation and checks its penetration to the Earth's surface. The thinning of this layer leads to an increase in solar UV-B radiation (280–320 nm) having potential deleterious consequences on agricultural production and natural plant ecosystems (Caldwell et al., 1995). An examination of susceptibility level for more than 200 plant species reveals that approximately 20% are sensitive, 50% are mildly sensitive or tolerant and 30% are completely insensitive to UV-B radiation (Teramura, 1983). UV-B radiation causes changes in morphological traits (González et al., 1998; Corriea et al., 1999; Yang et al., 2004) and physiological characteristics (Yang et al., 2007; Feng et al., 2003; Sullivan et al., 2003), and modifies the activities of antioxidant enzymes (Agrawal et al., 2009; Kumari et al., 2009). Damage to genetic material has also been reported under elevated UV-B radiation (Taylor et al., 1988; Mazza et al., 1999; Hidema et al., 2000; Tripathi et al., 2010). Plants develop a wide range of defensive strategies such as DNA repair, synthesis of UV-B absorbing compounds, thickening of leaves, etc. to compensate the damage caused by UV-B radiation (Schumaker et al., 1997; Jansen et al., 1998; Filella and Peñuelas, 1999).

In natural conditions, field plants are often exposed to multiple environmental factors such as temperature, drought, heavy metals, nutrients, etc., which may modify UV-B induced effects on plants (Prasad and Zeeshan, 2004; Singh et al., 2009; Agrawal and Rathore, 2007). Nutrient availability may alter the plant's response to sUV-B radiation (Singh et al., 2009). Phosphorus deficient soybean plants were less sensitive to UV-B than plants grown at optimum P levels due to the accumulation of secondary plant compounds and leaf thickening (Murali and Teramura, 1985). Nitrogen nutrition is a critical environmental factor for growth limitation, which also affects the capacity to produce plant pigments in leaves (Pintoo et al., 1999). Studies reported on response of radish to UV-B under natural field conditions at recommended dose of fertilizers reported increase as well as decrease in yield (Zavala and Botto, 2002; Nithia et al., 2005).

Sahoo et al. (2005) observed significant declining trend of total ozone column (TOC) over numerous stations lying in the northern part of India suggesting potential vulnerability of plants to UV-B under field conditions. Plants being stationary require an optimum level of soil nutrient to protect themselves from UV-B stress. To evaluate the interactive effects of sUV-B and NPK, a field study was conducted with radish (*Raphanus sativus* var Pusa Himani) under natural field conditions. The main objectives of the study were: (i) to evaluate the response of radish at supplemental UV-B_{BE} (+7.2 kJ m^{-2} d^{-1} biologically effective UV-B above ambient) on growth, biomass accumulation and allocation, yield and quality characteristics and (ii) the modification in above responses at different levels of nutrients and their combinations.

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0147-6513/$ - see front matter © 2010 Elsevier Inc. All rights reserved.
doi:10.1016/j.ecoenv.2010.12.011

2. Material and methods

2.1. Experimental site and plant material

The field experiment was conducted between February, 2007–April, 2007 and then repeated during February 2008–April 2008 (for yield characteristics) at the Botanical Garden of the Banaras Hindu University, Varanasi, Uttar Pradesh (25°81′ N, 83°1′ E and about 76 m above mean sea level) situated in the eastern Gangetic plains of India. Soil of the study site was sandy loam in texture (sand 45%, silt 28% and clay 27%) and had a pH value of 7.2. During the experiment, mean temperature ranged from 17.3 to 31.8 °C, mean relative humidity from 49.4 to 69.9% and rainfall was 136.9 mm. Photosynthetically active radiation (PAR) averaged 1200 ± 80 μmol m^{-2} s^{-1} at midday. The test variety of radish (*Raphanus sativus* L.var Pusa Himani) is developed from a cross of black with Japanese white, producing white, long (25–30 cm), thick tapering roots. Radish is known to be rich in ascorbic acid, folic acid, potassium and is also a good source of vitamin B_6, riboflavin, magnesium, copper and calcium.

2.2. Experimental design and nutrient application

The experimental design was a split plot with UV-B treatment as main plot and nutrient treatments as subplots randomized within the whole plots. Each treatment had three replicates. The experiment had three factors: (i) UV-B treatment, (ii) N, P and K amendment and (iii) plant-age. The four NPK amendments were recommended dose of NPK (F_0), 1.5 times recommended dose of NPK (F_1), 1.5 times recommended dose of N (F_2) and 1.5 times recommended dose of K (F_3). For convenience, control plants grown at ambient level of UV-B were designated as F_0C, F_1C, F_2C and F_3C with corresponding UV-B treated plants as F_0T, F_1T, F_2T and F_3T. The recommended doses of NPK were 100, 60 and 80 kg ha^{-1} given in the form of urea, super phosphate and muriate of potash, respectively. A half dose of N and full doses of P and K were given as basal dressings before sowing of seeds and another half dose of N was given as top dressings after 7 days of germination (DAG).

Before sowing the seeds, soil was sampled for estimating NPK levels and then the deficit from the recommended levels were added. N, P and K levels in the soil were 0.9, 0.4 and 0.2 mg g^{-1}, respectively, before sowing. The deficit amount added to reach the recommended concentrations of NPK in the soil are given in Table 1. The actual concentrations of NPK after addition of NPK are also given in Table 1. Radish seeds were sown on ridges in 24 plots of 1 × 1 m^2 each. For each treatment, three replicate plots were maintained. Spacing between ridges were 30 cm. Plants were thinned to keep a distance of 15 cm between the plants in each ridge for uniformity in growth. Plants were watered uniformly.

2.3. sUV-B treatment

sUV-B was artificially provided by Q-panel UV-B 313 40 W fluorescent lamps (Q panel Inc. Cleveland, OH, USA). Three lamps (120 cm long) per bank fitted 30 cm apart on a steel frame were suspended perpendicular to the planted ridge of each plot. The lamps were covered by either 0.13 mm cellulose diacetate filter (transmission down to 280 nm) for supplemental UV-B (sUV-B) or 0.13 mm polyester filter (absorbed radiation below 320 nm) for the control. The control plants thus received only ambient levels of UV-B radiation. Lamps in frames were adjusted weekly to a distance of 50 cm to provide a mean supplemental UV-B radiation of 7.2 kJ m^{-2} d^{-1} (unweighted) to plant apices for 3 h daily over the middle of photoperiod (11.00 a.m. to 1.00 p.m.).

Table 1
Recommended, deficit and actual amount of NPK added for attaining required NPK amount in the soil.

	Recommended NPK (kg ha^{-1})	1.5 × recommended NPK (kg ha^{-1})	1.5 × recommended N (kg ha^{-1})	1.5 × recommended K (kg ha^{-1})
Recommended amount	100:60:80	150:90:120	150	120
Deficit amount added	10:20:60	15:30:90	15	90
Actual concentrations of NPK	98.6:59.2:78.6	149.2:88.8:119.4	148.3	119.1

Table 2
Plant height, root length, number of leaves and leaf area of radish plants under sUV-B radiation at varying NPK levels. Values are mean ± 1SE.

Plant age (DAG)	NPK amendment (N)	Treatment	Plant height (cm $plant^{-1}$)	Root length (cm $plant^{-1}$)	Leaf area (cm^2 $plant^{-1}$)	Number of leaves ($plant^{-1}$)
20	F_0	C	27 ± 0.29	20.7 ± 0.35	613 ± 6.4	13 ± 0.58
		T	23.5 ± 0.50*	18.3 ± 0.33*	416 ± 21.9*	10.3 ± 0.88^{ns}
	F_1	C	29.9 ± 1.5	18.7 ± 0.28	656 ± 10.7	11.7 ± 0.88
		T	25.6 ± 2.9^{ns}	17.6 ± 0.23^{ns}	476 ± 11.5*	12 ± 0.001^{ns}
	F_2	C	25.1 ± 1.1	19 ± 0.29	515 ± 5.8	10.3 ± 0.33
		T	18.8 ± 0.83**	17.5 ± 0.29^{ns}	402 ± 3.5***	6.7 ± 0.33*
	F_3	C	17.9 ± 0.45	23.5 ± 0.29	228.3 ± 15.3	8 ± 0.58
		T	11.7 ± 0.33*	21.4 ± 0.40	177.7 ± 8.6^{ns}	8.7 ± 0.33^{ns}
40	F_0	C	36 ± 1.2	26.6 ± 0.99	790 ± 10	16 ± 1.2
		T	31.1 ± 0.61*	23.2 ± 0.61*	675 ± 14.4*	12.3 ± 0.67*
	F_1	C	35.5 ± 0.29	19.4 ± 0.49	970 ± 46.8	12.7 ± 0.8
		T	31.7 ± 0.35**	17.7 ± 0.29^{ns}	917.3 ± 17.1^{ns}	14 ± 1*
	F_2	C	34.1 ± 0.03	24 ± 1.2	773.3 ± 32.8	10.7 ± 0.7
		T	29.1 ± 0.95*	21 ± 0.58^{ns}	563.3 ± 76.2*	15.3 ± 1.8*
	F_3	C	22.9 ± 0.26	30.3 ± 0.67	528 ± 51.5	11.7 ± 1.3
		T	19.3 ± 1.33^{ns}	24.5 ± 0.48*	396.7 ± 76.2^{ns}	10.3 ± 0.8^{ns}
Results of three-way ANOVA						
Age (A)			371.7***	154.3***	266.1***	32.8***
NPK amendment (N)			115.2***	92.5***	123.7***	11.8***
Treatment (T)			79.6***	107.2***	61.8***	2.05^{ns}
A × N			1.59^{ns}	14.9***	6.70**	2.37^{ns}
A × T			0.229^{ns}	18.9***	0.011^{ns}	3.87^{ns}
N × T			0.915^{ns}	7.6***	0.860^{ns}	3.35*
A × N × T			2.07^{ns}	4.33*	2.73^{ns}	6.24**

Level of significance between control and sUV-B treated plants: ns, not significant.
F_0: recommended NPK; F_1: 1.5 times recommended NPK; F_2: 1.5 times recommended N; F_3: 1.5 times recommended K. N: nitrogen; P: phosphorus; K: potassium. sUV-B: supplemental UV-B.

* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.