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Impact of tropospheric ozone on growth and yield of garlic in high altitude region of Western Ghats

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Abstract
A pot culture experiment was conducted in TNAU- Climate Change Observatory, Woodhouse Farm, Horticultural Research Farm, Ooty during September-January of 2018-19 with the objectives of quantifying the garlic yield loss due to tropospheric ozone and identifying better ozone protectant for sustaining the garlic production against ozone. Twelve different treatments with Factorial Complete Block Design with three replications were tested on local garlic variety. Accordingly, most of the growth and yield parameters were significantly affected by higher levels of ozone where the treatment with ambient ozone exposure with ozone protectants was inferior in all parameters. Significantly the highest plant height (50.33 cm), fresh above ground biomass (23.10 gm), diameter of garlic (3.46 cm) and garlic yield (8.15 gm) were recorded on garlic plants in the ambient ozone exposure with 3% panchagavya treatment followed by ambient ozone exposure with 3% neem oil and ambient ozone exposure with 0.1% ascorbic acid treatments. The elevated ozone exposure treatments significantly decline the growth and yield parameters of garlic. From the results it implies that increase in the concentration of tropospheric ozone causes harmful effects on yield and growth of garlic whereby ozone protectants plays a major role by scavenging the O_3 in garlic.

Keywords: Ambient ozone, elevated ozone, ozone protectants, garlic, panchagavya

Introduction
The tropospheric and stratospheric layer of atmosphere contains Ozone. The stratospheric ozone is protecting the earth from harmful ultra violet (UV) radiation and the tropospheric ozone or ground level ozone is harmful to human, animals and plants. The tropospheric ozone is becoming major air pollutant recently, because of its increasing concentration, which could cause variety of health problems. It will also cause damage to the plants by entering through stomata, such as other gases enter. It will affect leaves and reduces the photosynthesis, growth and yield of crop plants.

Tropospheric ozone is formed via the photochemical oxidation of carbon monoxide (CO), methane (CH_4) or non-methane volatile organic compounds (NMVOCs) mainly from vehicle, solvents and industry in the presence of nitrogen oxides (NO_x, NO_x^{-} NO^{+} NO_2) (Unger *et al.*, 2006) [7]. The tropospheric ozone has been recognized as the main phytotoxic air pollutant in urban, suburban and rural area in developed and developing countries. In developing countries like India economic growth will require more energy production, which will result in increased production of NO_X and VOCs the precursors of ozone formation. In future global ozone trends have projected to increase rapidly on an average of 7.2 ppb within South Asia over next 20 to 30 years by 2030 which results in the highest O_3 concentration to be experienced by South Asia (Dentener *et al.,* 2005) [2]. Moreover, tropospheric ozone has been recognized as an important constituent of air pollutant and is considered to be phytotoxic air pollutant most significantly affecting vegetation (Booker *et al.*, 2009) [1].

In the Indo-Gangetic Plain (food basket of India), the ground-level O_3 could able to reduce crop production (Van Dingenen *et al.,* 2009) [8] moreover the increase in O_3concentration causes growth and yield reduction in food crops. Increase in the concentration of ozone suppresses the photosynthetic activity and stomatal conductance which results in premature leaf fall, reduction in biomass content and shows changes in physiology and growth of crops (Tetteh *et al.,* 2015) [5].

The ozone injury symptoms were reported in different crops such as Bean (*Phaseolus vulgaris*), Cucumber (*Cucumis sativus*), Grape (*Vitis vinifera*), Morning glory (*lpomoea purpurea*), Onion (*Allium cepa*) Potato (*Solanum tuberosum*), Soybean (*Glycine max*), Spinach (*Spinacia oleracea*), Tobacco (*Nicotiana tabaccum*), Watermelon (*Citrullus lanatus*) in different parts of the world (Kurpa and Manning 1988) [3]. This implies that the higher levels of ozone emitted in the atmosphere has the capacity to decline the agricultural productivity. Hence the study was taken to assess the impact of elevated tropospheric ozone on growth and yield of garlic.

Materials and Methods

Experimental Site and Design

A pot experiment was conducted by growing Ooty-1 variety of Garlic during season from September to December in 2018 at the experimental farm of the Tamil Nadu Agricultural University, Woodhouse Farm, Horticultural Research Station, Ooty. The site is located along the Western Ghats of Ooty at 11.4 °N, 76.7 °E, at an altitude of 2520m above mean sea level. The climate of the region is subtropical highland climate. The mean maximum and minimum temperatures from September to December are 25.2 and 10.6°C, respectively. Average rainfall of this area is 1564.3 mm annually, approximately 80% of which occurs during the kharif (monsoon) season.

Treatments

The experiment was carried out by growing garlic in pots and exposed to different levels of ozone in open top chambers (OTCs) with three treatments arranged in factorial completely randomized block design (FCRD) with three replications. The treatments were: T_1 – Ambient ozone level, T_2 – Elevated ozone exposure @ 150 ppb, T_3 – Elevated ozone exposure @ 200 ppb, T_4 – Ambient Ozone level + foliar spray 3% Panchagavya, T_5 – Ambient Ozone level + foliar spray 3% Neem oil, T_6 – Ambient Ozone level + foliar spray 0.1% Ascorbic acid, T_7 – Elevated ozone exposure @ 150 ppb + foliar spray 3% Panchagavya, T_8 – Elevated ozone exposure @ 150 ppb + foliar spray 3% Neem oil, T_9 – Elevated ozone exposure @ 150 ppb + foliar spray 0.1% Ascorbic acid, T_{10} – Elevated ozone exposure @ 200 ppb + foliar spray 3% Panchagavya, T_{11} – Elevated ozone exposure @ 200 ppb + foliar spray 3% Neem oil, T_{12} – Elevated ozone exposure @ 200 ppb + foliar spray 0.1% Ascorbic acid.

Observations were recorded on garlic crop for six characters namely, plant height (cm), diameter of bulb (cm), average bulb weight (g), number of cloves per bulb, weight of above ground biomass in fresh (cm) and weight of above ground biomass in dry (cm). The above characters were analyzed by one-way analysis of variance (ANOVA) and the significant differences between the means were determined with Duncan's multiple range test using SPSS version 16 to assess the impact of tropospheric ozone on plant and yield attributes of garlic.

Results

Growth parameters

Plant height (cm)

There was a significant difference observed among the treatments with respect to plant height due to the elevated tropospheric ozone on garlic. The highest value was recorded in T_4 (50.33 cm), T_5 (48.83 cm), T_6 (48.67 cm) and T_1 (48.33 cm) followed by T_7 (46.83 cm), T_8 (45.67 cm), T_9 (44.67 cm), T_{10} (43.33 cm), T_{11} (41.17 cm) and T_{12} (41.00 cm) which were on par. The lowest plant height was recorded in T_3 (36.83 cm) which was on par with T_2 (38.00 cm) (Table.1).

Table 1: Effect of tropospheric ozone on growth and yield of garlic

Treatments	Plant height (cm)	Above ground biomass (fresh) (gm)	Above ground biomass (dry) (gm)	No. of cloves/ bulb	Diameter of bulb (cm)	Weight of bulb (gm)
T_1 – Ambient ozone level	48.33 ± 4.177^{a}	19.79 ± 1.155^{cba}	3.24 ± 0.322	6.28 ± 0.722^{ba}	2.93 ± 0.029^{cb}	7.19 ± 0.252^{cb}
T_2 – Elevated ozone exposure @ 150 ppb	38.00 ± 2.000^{cb}	13.06 ± 1.109^{f}	2.41 ± 0.295	5.39 ± 1.020^{ba}	2.04 ± 0.087^{fe}	5.94 ± 0.271^{ed}
T_3 – Elevated ozone exposure @ 200 ppb	36.83 ± 3.655^{c}	12.69 ± 1.954^{f}	2.35 ± 0.036	4.78 ± 0.553^{b}	1.99 ± 0.081^{f}	5.72 ± 0.300^{e}
T_4 – Ambient Ozone level + foliar spray 3% Panchagavya	50.33 ± 4.256^{a}	23.10 ± 0.144^{a}	3.80 ± 1.154	7.33 ± 0.193^{a}	3.46 ± 0.128^{a}	8.15 ± 0.119^{a}
T_5 – Ambient Ozone level + foliar spray 3% Neem oil	48.83 ± 1.302^{a}	21.51 ± 0.641^{ba}	3.64 ± 0.083	7.00 ± 0.000^{ba}	3.23 ± 0.059^{ba}	7.32 ± 0.061^{b}
T_6 – Ambient Ozone level + foliar spray 0.1% Ascorbic acid	48.67 ± 2.906^{a}	20.35 ± 1.144^{cba}	3.51 ± 1.186	7.00 ± 1.000^{ba}	3.05 ± 0.079^{b}	7.26 ± 0.460^{cb}
T_7 – Elevated ozone exposure @ 150 ppb + foliar spray 3% Panchagavya	46.83 ± 3.468^{ba}	17.32 ± 2.429^{edf}	3.27 ± 1.071	6.22 ± 0.619^{ba}	2.65 ± 0.301^{dc}	6.78 ± 0.616^{dcb}
T_8 – Elevated ozone exposure @ 150 ppb + foliar spray 3% Neem oil	45.67 ± 0.601^{cba}	18.19 ± 0.444^{dcb}	3.31 ± 0.231	6.06 ± 0.817^{ba}	2.37 ± 0.089^{ed}	6.42 ± 0.147^{edc}
T_9 – Elevated ozone exposure @ 150 ppb + foliar spray 0.1% Ascorbic acid	44.67 ± 1.453^{cba}	16.82 ± 0.605^{edf}	2.92 ± 0.310	5.97 ± 0.640^{ba}	2.16 ± 0.023^{fe}	6.37 ± 0.030^{edc}
T_{10} – Elevated ozone exposure @ 200 ppb + foliar spray 3% Panchagavya	43.33 ± 1.922^{cba}	15.13 ± 0.265^{fed}	2.76 ± 0.216	5.89 ± 0.675^{ba}	2.39 ± 0.025^{ed}	6.13 ± 0.055^{ed}
T_{11} – Elevated ozone exposure @ 200 ppb + foliar spray 3% Neem oil	41.17 ± 1.641^{cba}	17.11 ± 0.287^{edf}	2.89 ± 0.726	5.83 ± 0.726^{ba}	2.25 ± 0.030^{fe}	6.08 ± 0.182^{ed}
T_{12} – Elevated ozone exposure @ 200 ppb + foliar spray 0.1% Ascorbic acid	41.00 ± 4.726^{cba}	14.32 ± 0.242^{fe}	2.65 ± 0.176	5.72 ± 0.722^{ba}	2.05 ± 0.035^{fe}	6.01 ± 0.147^{ed}
P value	0.049	0.000	0.846	0.429	0.000	0.000

Above ground biomass (fresh)

There was a significant difference observed among the treatments with respect to above ground biomass due to the elevated tropospheric ozone on garlic. The highest value was recorded in T_4 (23.10 gm) followed by T_5 (21.51 gm), T_6 (20.35 gm) and T_1 (19.79 gm) which were on par. The lowest value was recorded in T_3 (12.79 gm) and T_2 (13.06 gm) which were on par with T_{12} (14.32 gm), T_{10} (15.13 gm), T_6 (16.82 gm), T_7 (17.32 gm) and T_{11} (17.11 gm) (Table.1).

Above ground biomass (dry)

The dry weight of above ground biomass does not have significant difference among all the treatments. Even though, the highest value was recorded in T_4 (3.80 gm) and followed by T_5 (3.64 gm) whereas the lowest value was recorded in T_3 (2.35 gm) (Table.1).

Yield attributes

No. of cloves per bulb

The No. of cloves per bulb does not have any significant difference among all the treatments. However, the highest value was recorded in T_4 (7.33). The lowest value was recorded inT_3 (4.78) which was on par with T_2 (5.39), T_{12} (5.72), T_{11} (5.83), T_{10} (5.89), T_9 (5.97), T_8 (6.06), T_7 (6.22), T_1 (6.28), T_5 (7.00) and T_6 (7.00) (Table.1).

Diameter of garlic bulb

There was a significant difference observed among the treatments with respect to bulb diameter due to elevated tropospheric ozone on garlic. The highest value observed in treatment T_4 (3.46 cm), followed by T_5 (3.23 cm) which were on par. The next highest bulb diameter was observed in T_6 (3.05 cm) which was on par with T_5 (3.23 cm) and T_1 (2.93 cm). The lowest bulb diameter was observed in treatment T_3 (1.99 cm), which was on par with T_2 (2.04 cm), T_{12} (2.05 cm), T_9 (2.16 cm), T_{11} (2.25 cm) and T_{10} (2.39 cm) (Table.1).

Garlic yield

There was a significant difference observed among the treatments in which in T_4 (8.15 gm) recorded the highest value with respect to the garlic weight due to elevated tropospheric ozone. The next highest value observed in T5 (7.32 gm) which is on par with T_6 (7.26 gm), T_1 (7.19 gm) and T_7 (6.78 gm). The lowest value was recorded in T_3 (5.72 gm) followed by T_2 (5.94 gm), T_{12} (6.01 gm), T_{11} (6.08 gm), T_{10} (6.13 gm), T_9 (6.37 gm) and T_8 (6.42 gm) which were on par (Table.1).

Discussion

In the present study it is revealed that the garlic growth (plant height, fresh above ground biomass and dry above ground biomass) and yield parameters (weight of bulb, no. of cloves per bulb and diameter of bulb) are affected under elevated ozone exposures and ambient ozone exposures. Compared to the ambient ozone treatments, elevated ozone exposures are significantly influenced the reduction of plant height, fresh ground biomass, weight of bulb and diameter of bulb. The previous studies in India reported that the elevated ozone caused more decline in yield of *Triticum aestivum* and other cereal crops such as rice, maize etc. (Tomer *et al.*, 2012) [6]. Likewise the studies on potato which was carried by Kumari and Agarwal (2014) [4] reported that future prediction of increase in O_3 concentration shows negative effects on tuber yield, quality and size with the visual symptoms in leaves.

Conclusion

Due to the increase in concentration of tropospheric ozone in the atmosphere, it affects the yield and quality of crops. Hence the present study concludes that increase in the concentration of tropospheric ozone shows detrimental effects on growth (plant height, above ground biomass fresh and above ground biomass dry) and yield attributes (diameter of bulb, weight of bulb and no. of cloves per bulb) of garlic whereas the ozone protectants (panchagavya, neem oil and ascorbic acid) which are used in this study helps in scavenging the ozone in the apoplast of the crops. Moreover the tropospheric ozone effects on yield and quality of both agricultural as well as horticultural crops need more attention to withstand the productivity for future climate change scenarios. The tropospheric ozone concentration is increasing and has become potent greenhouse gas. Hence, the future focus would be to study the effect of tropospheric ozone on different food crop and identification of suitable remedial measures against tropospheric ozone to sustain our food production for ensuring food security.

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