ASSESSING THE IMPACT OF AMBIENT OZONE ON GROWTH AND YIELD OF CROP AT RAMPUR, CHITWAN

K. Kharel[1] and L. P. Amgain[2]

ABSTRACT

An experiment was conducted at Institute of Agriculture and Animal Science, Rampur, Chitwan, Nepal during March-July 2008 to explore the impact of ambient ozone on crop growth and yield. Mungbean cultivar "Pratikshya" was used as a test crop for the study. Mungbean plants were planted in 40 pots and 50% of the plants (i.e. plants in 20 pots) were treated with ethylenediurea (EDU) from 13 DAS to crop maturity at 10 days intervals. The ambient ozone level of the site was measured with passive samplers. The ozone level ranged from 29.3 to 39.1 ppb at the experimentation site during the cropping period. It was found that the ambient ozone at the site caused significant effects on plant growth and yield. The observed ambient ozone was found to reduce the growth parameters like plant height, per plant number of leaves, and number of branches by 10%, 27.74%, and 10.88%, respectively at 70 DAS while it reduced per plant number of seeds (13.17%), seed dry weights (19.67%), test weight (g/1000 seeds), (10.28%), total above-ground biomass (16.60%), harvest index (6.25%), and shelling percentage (5.07%) of controlled over EDU treated plants (ozone protected). The study clearly indicated that ambient ozone contributes to lower plant growth and crop yield.

Key words: Ambient ozone, ethylenediurea (EDU), passive sampler

INTRODUCTION

Ambient ozone is both an air pollutant and a greenhouse gas (Tonneijck and Van Dijk, 1997). Its concentrations have doubled since pre-industrial times, with average annual concentrations ranging from 20 to 45 ppb in the major parts of the world (Booker, 2007). In Asia, its concentration is alarmingly high with severe O3 episodes of 90–200 ppb in some large metropolitan areas of many countries (Emberson, 2007).

Ambient ozone is assumed to be the most important phyto-toxic air pollutant (US EPA, 1996; cited in Elagoz and Manning, 2002) and causes more damage to plants than all other air pollutants combined (USDA, 2000). Effects of elevated O3 concentration include a decrease in plant growth and an alternation in plant metabolism that would ultimately reduce the crop yield (Emberson et al., 2003). Furthermore, O3 sensitive plants frequently exhibit visible foliar injury, and also reduction in nutritional quality in some crops and forages (Booker, 2007). These effects may be due to effect of O3 in physiological processes of plants such as stomatal functioning, photosynthesis, respiration, and translocation of photosynthates (Chappelka and Chevone, 1992; Skarby et al., 1998; Musselman and Massman, 1999; cited in Kainulainen et al., 2000).

Emberson and Büker (2008) reported that current day concentrations of ground level O3 are commonly reducing crop yields by 5-35% of agriculturally important locations across south Asia. Since Nepal is sandwiched between two giant industrial nations, India and China, the ambient ozone concentration could have been contributed to lower crop yield in the country. But, no in-depth studies have been conducted in Nepal yet to assess effect of ambient ozone on crop yield.

[1] M.Sc. Agriculture, Ph. 12542923513, Email: kabboo17@yahoo.com
[2] Assistant Professor, IAAS, Rampur Chitwan, Email: lp_amgain@rediffmail.com

This study was an initiative on impact study of ambient ozone in Nepal. During the study, ambient ozone at the research site was measured and its effects were monitored on mungbean, an important summer crop in Nepal.

MATERIALS AND METHODS

The experiment was carried out at the Institute of Agriculture and Animal Science (IAAS), Rampur, Chitwan. It is situated at 27°37´N, 84°25´E and about 256masl. The duration of study was from March to July 2008 (while actual cropping duration was April-June). The air temperature and relative humidity of the research site were measured with Tinytag (a data logger). The passive samplers (5 pairs provided by IVL Laboratory, Sweden) were used to measure the ozone concentration integrated over time. Approximately 10 liter volume pots with a 25 cm surface diameter and 30 cm height were used for experimentation. Approximately 8.5 kg of soil-mix (local soil: sand: compost = 1:1:1) was used per pot. The composite sample was analyzed at Soil Management Directorate, Hariharbhavan, Lalitpur, Nepal. The result of the test is presented in Table 1.

Table 1: Soil used in experiment (2008)

Details	Results	Remarks
pH	5.5	Acidic
N (%)	0.13	Medium
P_2O_5 (kg ha^{-1})	67	High
K_2O (kg ha^{-1})	298	High
Organic Matter (%)	2.6	Medium

Approximately 30g locally available fertilizer Samadhan (NPK in the ratio of 19:19:19) and 1g micronutrient MgO were mixed in the soil and applied in each pot for balanced nutrient supply. Each pot was provided with three fiberglass wicks extending to the water reservoirs below them. This method of watering plants was applied to check the rapid downward movements of EDU during irrigation.

On April 7 2008, three seeds of mungbean cultivar "Pratikshya" were sown per pot. At 10 DAS, they were thinned to one plant per pot. Thus, only one plant per pot was exposed to ambient ozone in the field. At 13 DAS, 50% of the plants (i.e. alternate 20 pots) were treated with 100ml of 400ppm freshly prepared EDU solution in distilled water. The EDU application was repeated in every 10 days until the maturity of reproductive parts with an increasing volume of 50ml at every 20 days. Controlled plant was treated with the similar volume of only distilled water.

Weeds were removed from the pots and around the pots as necessary throughout the experimental period. Watering was done through the fiberglass wicks that were projected into the water reservoir (water bucket) and through natural rainfall. As plant protection measures, organic pesticide "Azadaractin" and "Servo" were applied because they were supposed to have neutral interactions with ozone. Harvesting of mungbean was done when pods were turned brown. Three pickings were done within a week period.

Plant heights, per plant number of leaves, and branches of both control and EDU treatments were recorded at 40, 50, 60, and 70 DAS while yield parameter were calculated at crop harvest.

The data recorded on different parameters were analyzed with paired t-test using SPSS software program.

RESULTS AND DISCUSSION

AMBIENT OZONE AND METEOROLOGICAL RECORDINGS

Ambient ozone concentration accumulated over time, maximum and minimum air temperature, and the relative humidity data for the experimental period are presented in Fig.1.

The ambient ozone level was measured at 28 days interval. Highest level of mean ozone concentration (39.1ppb) was observed during April 27 to May 24 and lowest level (17.1ppb) was observed during June 22 to July 19 2008. However, 29.3 to 39.1ppb of ambient ozone level were recorded during crop period (April – June, 2008) This study clearly shows that the periods with high temperature, long sunshine hours, less rainfall, and minimum RH favor the highest level of ozone concentration. This is consistent with the finding of Agrawal et al. (2005) who reported that the high temperature with long light duration favored O3 formation due to long range transport of ozone precursors. Similarly, USDA (2000) observed high concentrations of ozone during calm, sunny, spring and summer days.

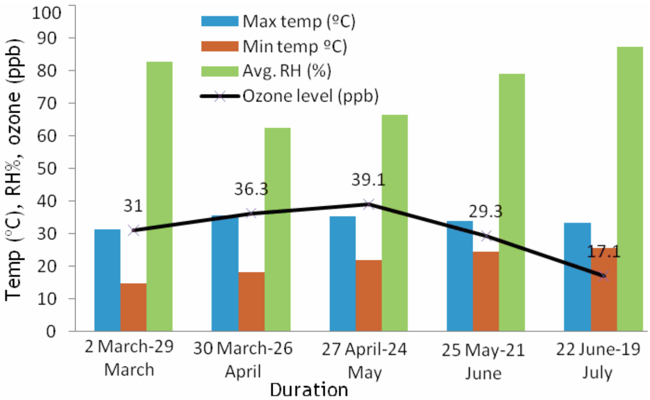

Fig.1: Ambient ozone and meteorological recordings during experimental period (2008)

PLANT GROWTH ATTRIBUTES

Mean plant height, per plant mean number of leaves, and the mean number of branches of mungbean under control (Non EDU), and EDU treatments during different observations are shown in the Table 2.

Table 2: Measurement of growth parameters of mungbean (Mean±S.E.) (2008)

Days after sowing (DAS)	Control	EDU treated	% reduced due to ambient ozone
Plant height			
40	30.80± 1.25	32.50 ± 1.19	5.23
50	36.86± 1.10	41.14 ± 1.22*	10.40
60	39.64 ± 1.16	44.02 ± 1.17*	9.95
70	40.41 ± 1.23	44.90 ± 1.13*	10
No of leaves/plant			
40	29.35± 1.14	31.05 ± 1.11	5.47
50	35.65 ± 1.75	40.35 ± 1.60*	11.64
60	32.20 ± 2.26	39.85 ± 1.94**	21.33
70	28.00± 2.18	38.75 ± 2.47**	27.74
No of branches/plant			
40	4.00 ± 0.27	4.15 ± 0.22	3.61
50	5.95 ± 0.34	6.50 ± 0.32	8.46
60	7.45 ± 0.39	8.35 ± 0.30	10.77
70	8.60 ± 0.31	9.65 ± 0.25*	10.88

Significant differences between control and EDU treatment are indicated as: * = p<0.05 and ** = p< 0.01

Plant height

No significant difference in plant height was observed during earlier plant growth period. However, significant difference in plant height (i.e. higher plant height) was observed after

50 DAS onwards with EDU treated plant than control ($p<0.05$). At 50 DAS, plant height was reduced by 10.40% in control plants than in EDU treated plants. At 60 DAS and 70 DAS, the plant heights were lesser by 9.95% and 10%, respectively in control than in EDU treatments. At the crop maturity, the reductions in plant height in control compared to EDU were smaller than expected. This fact may be due to the breakage of tips of some plants at later stages of growth. However, almost 10% reduction was noticed even at 60 DAS and 70 DAS. It is clear that EDU played significant role to lessen ozone effect in EDU treated plants while control plants were affected by ambient ozone.

Agrawal *et al*. (2005) also reported similar findings under ambient conditions. They reported 12.3% increase in plant height of EDU-treated mungbean at 80 DAS in the experiment carried under ambient conditions in India. They also reported significant difference in plant height at later stages compared to early stages. Increased response of plants with time on compounding of the ozone effect could be the reason for this as reported by Morgan *et al*. (2003).

Number of leaves per plant

The number of leaves per plant was almost similar in both EDU treated and control plants up to 40 DAS. But, there was significant difference between the number of leaves of control and EDU plants after 50 DAS. Percent reduction in control plants were 5.47 %, 11.64 %, 21.33 % and 27.74 % compared to EDU treated plants at 40, 50, 60 and 70 DAS, respectively. This decreased numbers of leaves per plant in control plants might be due to the effects of ozone whereas the increasing trend in percent reduction might be due to the cumulative action of EDU on plants to build up counter-ozone quality. Similar findings were reported by Tonneijck and Van Dijk, (1997). They reported less number of leaves of Trifolium subterraneum on ozone exposure but higher number of leaves with the application of EDU.

Further, lesser numbers of leaves were noticed per plants at 60 and 70 DAS in both control and EDU treatments; however, severe losses of leaves were observed in control plants. This decreased numbers of leaves in control plant (Non-EDU) may be due to severe senescence during the later stage of plant life as stated by Booker (2007). He reported leaf senescence as one of the most common effects of ambient ozone in plants. Harti et al. (1995) found defoliation of leaves was relatively earlier in non EDU plants than EDU plants of *Phaseolus vulgaris* L.

Number of branches per plant

During 40 to 60 DAS, the mean numbers of branches per plant in EDU treated plants were higher than in control plants though they were not statistically different ($p>0.05$). But, the mean numbers of branches per plant in EDU treated plants was significantly higher at 70 DAs than in control plants ($p<0.05$). It was noticed that ambient ozone reduced the number of branches of control plants by 3.61 %, 8.41 %, 10.77 % and 10.88% at 40, 50, 60, and 70 DAS, respectively. Manning et al. (2004) also reported lower number of branches in apple trees grown at high ozone level.

Root dry weight

Dry roots of each plant of both the control and EDU treatments were weighed at final harvest. The observations are shown in Table 3. The mean root dry weight was observed significantly higher in EDU treated plants compared to control ($p<0.05$). It might be due to effect of EDU on plants as reported by Harti, et al. (1995) in bean (*Phaseolus vulgaris* L.) in open-top field chambers experiment. While, in contrast, Perera and Wijesooriya (2007) reported slightly higher root dry weight in Non-EDU plants of mungbean under ambient conditions. They also added that plants under any stress conditions may increase their root biomass as a mechanism for better survival.

Plant yield attributes

Different yield parameters: per plant number of seeds, seed dry weight, seed test weight, above ground biomass, harvest index (HI) and shelling percent of both control and EDU treated plants were observed at harvest and are presented in Table 4.

Seed dry weights per plant and above ground biomass were highly significant in EDU treated plants than control ($p < 0.01$). Also, the number of seeds per plant and shelling percentage were significant ($p<0.05$) in EDU treatment compared to control. Besides, the harvest index was found at par between treatments. The mean number of seeds per plant, dry weight of seeds per plant and test weight of seeds were reduced by 13.17%, 19.67%, and 10.28%, respectively in control plants over EDU treated ones.

Table 3: Mean root dry weight (g) of mungbean plant at final harvest (Mean±S.E.) (2008)

Parameters	Control	EDU treated
Dry root weight	1.22 ± 0.05	1.42 ± 0.04*
CV%	20.68	14.63

Significant difference between treatments is indicated by * ($p< 0.05$)

Fumagalli et *al*. (2001) reported 17–39% yield loss in crops such as wheat, bean, watermelon and tomato in ambient conditions. Increment in the number of seeds per plant in EDU treated plants further suggested a protective role of EDU under elevated O3 levels. Wahid et al. (2001) reported that EDU treatment increased 47% and 94% in seed weight per plant in soybean (*Glycine max* L.) at the sub-urban sites and at the rural sites of Punjab, Pakistan. Similarly, test weight of mungbean plant at ambient ozone was found to be increased by 25.3 % in EDU treated plants over control ones (Agrawal et al., 2005). Tiwari et al. (2005) have reported an improvement of seed yield in wheat (*Triticum aestivum* L) by applying EDU under ambient conditions.

Table 4: Measurement of yield parameters of mungbean (Mean±S.E.) (2008)

Yield Parameters	Control	EDU treated	% Reduced due to ambient ozone
No of seeds/plant	173.35 ± 9.25	199.65 ± 6.47*	13.17
Seed dry weight/plant (g)	5.92 ± 0.28	7.37 ± 0.23**	19.67
Test weight of seed (g)	33.15	36.95	10.28
Above ground biomass (g)	18.98 ± 0.58	22.76 ± 0.67**	16.60
Harvest Index (HI)	0.30 ± 0.01	0.32 ± 0.01	6.25
Shelling%	63.81 ± 0.93	67.22 ± 0.64*	5.07

Sig.nificant difference between treatment sis indicated by * ($p< 0.05$) and **($p< 0.01$)

Total above-ground biomass of each plant, harvest index and shelling percent were reduced by 16.60%, 6.25% and 5.07%, respectively in control plants over EDU treated. It might be due to higher ambient ozone level at the site. Krupa et al. (2001) found depressed plant biomass due to high ozone. Harti et al. (1995) also found that the increased O3 concentration significantly decreased shoot biomass of *Phaseolus vulgaris* L. whereas EDU treated plants had higher biomass than control ones. Similarly, Astorino et al. (1995) reported 57 % reduction in the total above-ground biomass on bean (*Phaseolus vulgaris* L.) near-ambient level of ozone. Moreover, he suggested that increment in number of pods and seeds/pod and test weight due to EDU-treatment contributed to higher harvesting index of EDU treated plants as compared to control ones.

CONCLUSION

This study suggests that the ambient ozone at Rampur, Chitwan is high enough to cause significant loss on growth and yield of mungbean. However, different crops may have different responses to ambient ozone. Ozone level measurements at different locations across the country and impact study in different crops may reveal the actual scenarios of ambient ozone level and its impacts in Nepal.

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