Bull. Environm. Contam. Toxicol. 20, 657-661 (1978)

Ethylene Pollution from Wheat Stubble Burning

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INTRODUCTION

Wilful burning of small grain stubble is an age-old practice in Greece to facilitate seedbed preparation for the next crop. It is estimated that about 1 million hectares of small grain fields, mostly wheat, are burned each year after harvest. Although the beneficial and harmful effects of this practice are frequently discussed from a strictly agronomic viewpoint, no attention has so far been given in this country to agricultural burning as a source of air pollution. Apart from general environmental hazards the practice is of particular interest as a potential source of injury to high value horticultural crops because of the phytotoxicity of some of the gases emitted during plant residue burning. Ethylene, is the most abundantly contained gas in the smoke (McELROY 1960). The ethylene generated by burning plant material was found to be 1 kg and 2.7 kg per ton of wood chips and green brush, respectively (DARLEY et al. 1966). For plant paterial burned in grass fields BOUBEL et al. (1969) reported a value of 0.772 kg. Nonagricultural sources of ethylene pollution are automobile exhausts, kilns, fuel consuming space heaters etc.

Ethylene is an intriguing air pollutant because it is also a naturally occurring plant hormone. Although its hormonal action has been studied extensively, its importance as a pollutant has drawn less interest as compared to other gases mainly because its toxicity concerns plants and not humans.

Generally, ethylene concentrations required to affect plants in some way (not necessarily phytotoxically) should exceed the threshold concentration of 0.01 ppm while saturation is reached at values of 1 to 10 ppm (ABELES 1973). The effect however varies greatly with the duration of exposure to a certain concentration and with the species. Also, the various plant organs may vary in their sensitivity to critically high concentrations. DAVIDSON (1949) tested various combinations of concentrations and durations of exposure and found 0.02-0.002 ppm for 24 h as the minimum conditions to cause injury to orchid flowers. Nevertheless, it must be pointed out that orchids are particularly sensitive to ethylene and most crops can stand much higher concentrations without any signs of injury. Economic losses due to pollution from ethylene produced by anthropogenic sources were reviewed and summarized by ABELES (1973) for several crops. These losses are not only from direct injury but also from indirect, commercially undesirable, influences on plant development.

0007-4861/78/0020-0657 $01.00

The ethylene concentrations in rural areas (when no burning of residues occurs) reported in the review by PRATT and GOESCHL (1969) are about 0.003 ppm therefore are physiologically insignificant while in cities concentrations ten times as high have been reported. On the other hand, when plant residues are burned, the concentrations in rural areas may rise considerably as shown by McELROY (1960).

We conducted this study as a first step towards evaluating the environmental consequences of agricultural burning which is practised without any control in the wheat lands in Greece. The tests conducted so far were limited to ethylene only because of the specific importance of this substance for plant development.

MATERIALS AND METHODS

The tests were carried out under both confined and free diffusion conditions in the University of Thessaloniki Farm in the fall of 1977. Air samples were collected in 2.5 ml plastic syringes and ethylene content was determined by gas chromatography with a Varian Chromatograph model 2740 equipped with a 1/8"x4 column of activated alumina and a flame ionization detector. The column temperature was 50°C with a N_2 carrier gas flow of 40 ml/min.

Confined diffusion tests: We burned 30 kg of wheat straw in the center of the floor of an empty warehouse whose dimensions were 29 mx22 mx5 m. Doors and windows were closed but not hermetically sealed. The straw was tightly packed and contained 20% moisture. One hour after complete burning of the straw we sampled the air of the warehouse at heights of 1, 2, 3, and 4 m from the floor. Two samples were collected from each height. We also burned 0.5 kg of straw containing 20% moisture, placed loosely within a closed barrel of 0.200 m^3 volume. Thirty minutes after complete burning we collected randomly five air samples from various points in the barrel.

Free diffusion tests: We selected a 200 mx100 m wheat field which had been harvested 4 months earlier and left undisturbed since that time. The soil was dry with cracks reaching to a maximum depth of about 30 cm. The straw residue of the field was about 25 cm high and weighed an average of 0.5 kg/m^2. This residue contained 24% moisture at the time of the test. Five concentric hexagons were marked with numbered stakes in the middle of the field. The corners of the innermost hexagone were 2 m from the center. Spacing of hexagons was 1 m. At 10:00 h fire was set to the residue at the center. Two minutes later when the burning area was about 0.5 m^2 a first sampling was carried out followed by a second one 5 minutes after the first. The samples were collected by hand simultaneously by persons placed at the corners of each hexagon at 1 m aboveground. Thirty minutes later and when an area of about 200 m^2 was burning vigorously air samples were collected on a transect following the wind and at distances of 10, 30 and 90 m from the burning front. Also, air samples were taken from soil cracks of 10-20 cm depth 1 h after burning ceased. During the tests wind speed was less than 1 m/sec., air temperature 16°C and air relative humidity 72%, as recorded by instruments placed about 500 m from the test site.

RESULTS AND DISCUSSION

The highest concentration of ethylene found in this study was in the barrel and amounted to 628 ppm. This value is in the same order of magnitude as the values reported for autoexhausts (McELROY 1960). The burning test in the warehouse showed values of 0.291, 0.673, 1.620 and 2.340 ppm at aboveground heights of 1, 2, 3 and 4 m respectively or a mean of 1.231 ppm for the whole volume of the warehouse. Preburn levels in the warehouse were the same as outside (see below). The capacity of the wheat straw to produce ethylene when burned under the conditions of the two tests was 364 g and 189 g of ethylene per ton of dry material for the barrel and the warehouse tests, respectively. These values are much lower than the ones reported by DARLEY et al. (1966) for wood ships and green brush while they are comparable to the ones reported by BOUBEL et al. (1969) for plant material in grass field. The very high value found for green brush may be attributed to the high moisture contained in that fresh material. Also, differences due to the origin of the plant material itself and to burning conditions must be expected. On the other hand, the difference in the values obtained from our two tests in which the same material was burned may be attributed to the different conditions which undoubtedly prevailed during the tests, e.g., oxygen availability, smoke losses from small cracks in the warehouse etc.

Preburn concentrations of ethylene 1 m above the ground of the wheat stubble field were less than 0.030 ppm while in soil cracks values of 0.055 ppm were recorded. The data on ethylene concentrations 2 and 5 min after burning started in the field test (Fig. 1) show clearly some ethylene enrichment which, however, was uneven because it occurred at the sides towards which the wind was blowing. At the opposite sides preburn values with a mean of 0.026 ppm and a range of 0.009-0.036 ppm were recorded. Determinations made 10 m away from the burning front (at the side the wind was blowing) 30 min after burning started, showed 0.415 ppm while 30 m away preburn levels were found. As compared to the findings of McELROY (1966) the results of our field tests showed considerably less enrichment. In McELROY's test the burning area was much larger. Finally, it must be added that air samples collected 1 m above the intensively burning stubble showed values ranging from 2.110 to 28.510 ppm, and soil cracks 1 h after all burning ceased contained 1.865 ppm while the air concentrations just 1 m above those cracks at the same time had dropped to preburn levels.

The evaluation of the importance of agricultural burning as a cause of damage to plants and as a source of general environmental pollution in Greece , requires many further tests and perhaps even a long range monitoring program not only for ethylene but for other gases too which are emitted from burning wheat and other stubble. The high diffusivity of ethylene generated by stubble fires in open spaces would seem to lower the importance of this substance as a source of phytotoxicity or even as a source of undesirable interference with plant development. The fact however, that we found ethylene in physiologically important concentrations (1.865 ppm) within the soil cracks of the area burned 1 h previously suggests that stubble

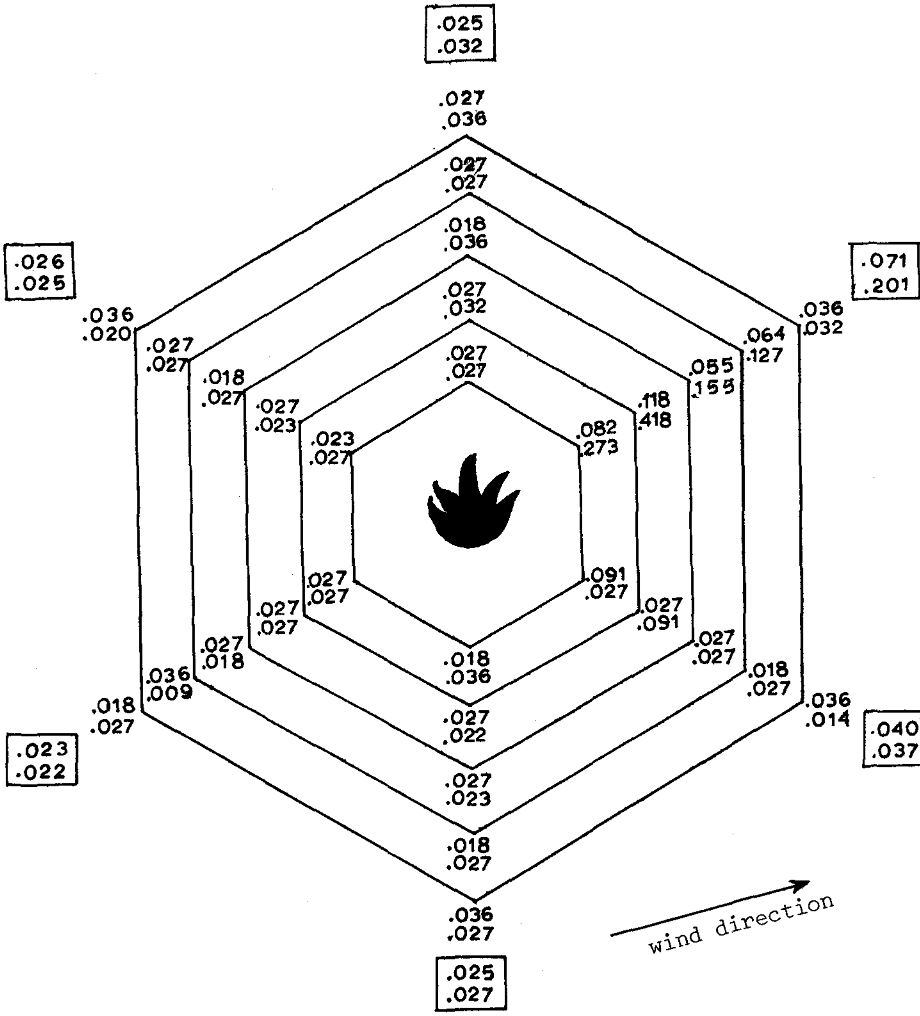

Fig. 1. Ethylene concentrations (ppm) at 1 m aboveground around a small area of burning wheat stubble. Upper and lower values at each hexagon's corner show results of determinations carried out 2 and 5 min after fire was set, respectively. Numbers in squares are means of the values of the respective concentric corners. Hexagon spacing is 1 m.

burning may affect plant growth either directly by inhibiting root growth or indirectly by affecting soil microflora. These concentrations are much in excess of those found in other studies to reduce strongly root extension in cereals and certain dicotyledons (SMITH et al. 1970). On the other hand BALIS (1976) working with some Greek soils showed that ethylene induced volatile inhibitors causing fungistasis. We consider this line of research as worthy of further attention.

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