UNIVERSITI PUTRA MALAYSIA

MEASUREMENT OF GROWTH, PHOTOSYNTHESIS AND TRANSPIRATION RATES OF A MALAYSIAN LOCAL RICE CULTIVAR (MR 219) FOR ASSESSING AMBIENT OZONE STRESS

NURUL AZZURA BT SHAHADAN.

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By

NURUL AZZURA BT SHAHADAN

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia in Fulfilment of the Requirements for the Degree of Master of Science

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DEDICATION

Specially dedicated to:

'Ayah & Ibu'

'Nik Noor Ezeky'

'Nik Dianah Wafiah'

And My Family

This thesis is not been so easy without you......

Abstract of thesis presented to Senate of Universiti Putra Malaysia in fulfilment of requirement for the degree of Master of Science

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Ambient air pollution has been shown to reduce the yield of several major crops species. Research and field observations have suggested that O_3 may responsible for up to 90% of the crop loss induces by air pollutants. One approach that has been used to estimate effects of ozone on yield is by determination critical O_3 levels cumulated exposure over the threshold of 40 ppb (AOT40). The AOT40 is calculated as the sum of the differences between the hourly ozone concentrations in ppb and 40 ppb for each hour when the concentration exceeds 40 ppb.

This study is aimed to investigate the responses of Malaysian local rice cultivar (MR 219) to current ambient ozone (O_3) in Muda Agricultural Development Authority (MADA). Open top chambers that ventilated with ambient air and charcoal-filtered air was used to assess the impact of air pollution on the physiology and growth of rice. The rice crop was grown according to the local crop management practice with respect to the rate of fertilizer and pesticides application and water supply.

The result showed the plant height in the non-filtered chamber decreased by 2.8% at vegetative stage, 12.1% at reproductive stage and 6.1% at ripening stage as compared to the crop grown in the filtered chamber. Average number of tillers per point in the filtered chamber was 14, with a maximum of 29, whereas for non-filtered chamber it was 11 with a maximum of 24.

In general, the relative growth rate (RGR_{dw}) for all plant parts were higher in stage I than in stage II and III. The statistical analysis of RGR_{dw} for all plant parts were not significant different at 95% confident level.

The study also indicated that the pollutant affected the physiology most during the vegetative stage. Photosynthesis rate (P_g) was observed to be significant different at the 95% confident level between filtered and non-filtered plant at vegetative stage. Photosynthetic capacity (P_{max}) in filtered plant was 18.8 μmol CO_2 m^{-2} s^{-1}, and 12 μmol CO_2 m^{-2} s^{-1} in non-filtered plant during the vegetative stage. At reproductive stage the difference in photosynthesis rate between filtered and non-filtered plant was not significant (95% confident level). Photosynthetic capacity (P_{max}) in the non-filtered plant was 13.9 μmol CO_2 m^{-2} s^{-1}, and 13.5 μmol CO_2 m^{-2} s^{-1} for the filtered plant.

The transpiration rate (*E*) differences between the plants in the filtered and non-filtered chamber was significant (95% confident level) during the vegetative stage but not during reproductive stage. The differences in stomata conductance between the filtered and non-filtered plants during the vegetative and reproductive stages were not significant (95% confident level).

At the final harvest, the differences in yield between the filtered and non-filtered chambers at 95% confidence level was significant. The average of total weight of grain in the filtered chamber was 120.7g per plant and 90.97g per plant in non-filtered chamber. The mean 100 yields grain weight for filtered and non-filtered chambers were 2.71g and 2.57g, respectively. However, the difference between 100 filled grain weight for the two chambers was not significant (95% confidence level).

Abstrak tesis yang telah dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains

PENGUKURAN KADAR PERTUMBUHAN, FOTOSINTESIS DAN TRANPIRASI BAGI CULTIVAR PADI TEMPATAN MALAYSIA (MR 219) BAGI MENGGARISKAN TEKANAN OZON KASA

By

NURUL AZZURA BT SHAHADAN

Julai 2005

Pengerusi: Profesor Madya Ahmad Makmom B. Hj Abdullah, PhD

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Pencemaran udara kasa telah menunjukkan pengurangan hasil bagi beberapa tanaman utama. Kajian dan pemerhatian yang telah dijalankan mendapati O_3 bertanggungjawab terhadap 90% pengurangan tanaman disebabkan pencemaran udara. Salah satu kaedah yang digunakan bagi menjangkakan kesan ozone terhadap hasil ialah penentuan kadar kritikal ozon kumulatif apabila pendedahan melebihi 40 ppb (AOT40). AOT40 dikira sebagai jumlah perbezaan diantara kepekatan ozon setiap jam bagi ppb atau 40 ppb apabila kepekatan ozon melebihi 40 ppb untuk setiap jam.

Kajian ini bertujuan, untuk mengkaji tindak balas cultivar tempatan Malaysia (MR 219) terhadap ozon udara kasa di kawasan Muda Agricultural Development Authority (MADA). Kebuk fumigasi terbuka dengan pengaliran udara kasa dan pengawalan udara digunakan bagi melihat kesan pencemaran udara terhadap pertumbuhan dan fisiologi pokok padi. Pokok padi membesar mengikut cara amalan pengurusan tanaman tempatan dengan memberi perhatian terhadap jumlah baja dan penggunaan racun serangga dan juga pengaliran air.

Keputusan menunjukkan ketinggian pokok di dalam kebuk fumigasi tidak bertapis berkurangan sebanyak 2.8% pada peringkat pertumbuhan, 12.1% pada peringkat reproduktif dan 6.1% pada peringkat matang berbanding dengan ketinggian pokok dalam kebuk fumigasi bertapis. Purata bilangan batang untuk setiap bahagaian dalam kebuk fumigasi bertapis adalah 14 batang dengan bilangan maksimum sebanyak 29 batang, manakala bagi kebuk fumigasi tidak bertapis, ianya adalah sebanyak 11 batang dengan bilangan maksimum 24 batang.

Umumnya, kadar pertumbuhan relatif (RGR_{dw}) bagi semua bahagian pokok padi pada peringkat I adalah lebih tinggi berbanding peringkat II dan III. Analisis statistik RGR_{dw} bagi setiap bahagian pokok adalah tidak menunjukkan perbezaan bermakna pada tahap keyakinan sebanyak 95%.

Kajian ini juga mendapati pencemar lebih memberi kesan terhadap fisiologi pada peringkat pertumbuhan vegetatif. Kadar fotosintesis pada peringkat vegatatif menunjukkan perbezaan bermakna diantara tumbuhan bertapis dan tidak bertapis adalah pada tahap keyakinan sebanyak 95%. Kapasiti fotosintesis (P_{max}) pada peringkat vegatatif adalah 18.8 µmol CO_2 m^{-2} s^{-1} pada pokok dalam kebuk fumigasi bertapis dan 12 µmol CO_2 m^{-2} s^{-1} di dalam kebuk fumigasi tidak bertapis Pada peringkat reproduktif, kadar fotosintesis menunjukkan tidak terdapat perbezaan bermakna antara pokok bertapis dan tidak bertapis. Kapasiti fotosintesis (P_{max}) dalam kebuk fumigasi tidak bertapis adalah 13.9 µmol CO_2 m^{-2} s^{-1} dan 13.5 µmol CO_2 m^{-2} s^{-1} bagi kebuk bertapis.

Kadar transpirasi bagi pokok di dalam kebuk fumigasi bertapis dan kebuk fumigasi tidak bertapis menunjukkan perbezaan bermakna pada peringkat pertumbuhan vegetatif tetapi situasi sebaliknya pada peringkat reproduktif. Perbezaan alir stomata diantara pokok dalam udara bertapis dan tidak bertapis menunjukkan perbezaan tidak bermakna bagi kedua – dua peringat pertumbuhan vegetatif dan reproduktif dengan tahap keyakinan sebanyak 95%.

Pada peringkat penuaian terakhir, perbezaan hasil di dalam kebuk bertapis dengan tidak bertapis menunjukkan tahap keyakinan sebanyak 95%. Purata jumlah berat bijian bagi setiap pokok adalah 120.7g bagi kebuk fumigasi bertapis, dan 90.97g dalam kebuk fumigasi tidak bertapis. Purata berat bagi 100 bijian berisi dalam kebuk fumigasi bertapis dan kebuk fumigasi tidak bertapis adalah masing-masing 2.71g dan 2.57g. Walaubagaimanapun perbezaan berat 100 bijian berisi diantara kebuk fumigasi tersebut adalah tidak bermakna dengan tahap keyakinan sebanyak 95%.

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LIST OF ABBREVIATIONS

Carbon monoxide	CO
Cumulative exposure over the threshold concentration of 40ppb	AOT40
Curvature rate	θ
Filtered	F
Hydrogen Fluoride	HF
Malaysia Agriculture Research and Development Institute	MARDI
Muda Agricultural Development Authority	MADA
Muda Irrigation Scheme	MUDA
Malaysia Meteorological Services	MMS
Nitric oxide	NO
Nitrous oxide	N_2O
Non-filtered	NF
Oxides of nitrogen	NOx
Oxygen	O_2
Ozone	O_3
Open top chamber system	OTCs
Photosynthetic active radiation	PAR
Part per Million	ppm
Part per Billion	ppb
Photosynthesis rate	P_g
Photosynthesis capacity	P_{max}
Photosynthesis efficiency	α
Stomata Conductance	G_s
Sulphur Dioxide	SO^2

Transpiration	E
United Nation Economic Commission for Europe	UNECE
Volatile organic compounds	VOCs

CHAPTER 1

INTRODUCTION

Rice, (*Oryza sativa L.*) is a major food source for many of the people in the world, especially in Asia. More than half of the world's population relies on rice as the major daily source of calories and protein. According to FAO (2001), the amount of rice consumed by each of these people ranges from 100 to 240 kg per year. More than four-fifths of the world's rice is produced and consumed by small-scale farmers in low-income and developing countries.

During the Green Revolution (1966-1990), the increase in the world rice production has resulted in more rice being available for consumption despite the continued increase in population. However there are still some 815 million people in the world suffering from hunger and malnutrition, most of them live in areas that depend on rice production for food, income and employment (FAO 2001). In recent years, the world's rice production has suffered from the lack of investment in irrigation development and research work. This had slow down the adoption of existing high yielding varieties and improved crop management technique.

There are three factors that affecting crop growth and development namely determining factors, limiting factors and reducing factors (Lansigan, 1998). Growth and yield determinants include meteorological variable such as temperature, rainfall and solar radiation. Crop and yield limiting factors comprise abiotic resource such as water and nutrient which limit crop growth and development when their supply is sub optimal during part or whole duration of the cropping season. Growth and yield reducing factors include biotic factors such as pest, disease and weeds and also abiotic factors that is pollution. The open top chamber system (OTCs) is the best approach for the studying the impact of pollutant on crops (Heck, 1990). OTC is able to provide an enclosed environmental area for a various type of treatments at near ambient environmental conditions. As an equator country, they were having a high temperature, solar radiation and rainfall that supply the plant growth. In Malaysia, proper management practice from Muda Agriculture Development Authority (MADA) will certainly minimize the negative effects from abiotic and biotic factors. An only pollution factor was cannot be controlled.

Economic assessments of the effects of ozone on crop yields have been undertaken in the USA since the mid-1980s (Heck, 1989). The first such analysis in Europe was performed by Van der Eerden *et al* in 1988 for the Netherlands, considering the effects not just of ozone (O_3), but also of sulphur dioxide (SO_2) and Hydrogen Fluoride (HF). Ozone, a colorless gas, forms in the lower atmosphere as a result of chemical reactions between oxygen (O_2), volatile organic compounds (VOC) and nitrous oxide (N_2O), in the presence of sunlight, especially during hot weather (EPA, 1992). Sources of ground level ozone include; vehicles, factories, industrial solvents, gas stations, and farm equipment, to name a few (EPA, 1992). Ground level ozone damage is estimated to reduce crop yields from 2-5% (NAPAP, 1991). Ozone (tropospheric) at lower elevations adds to the warming process. Its formation is catalyzed by other gases such as nitric oxide (NO). In the troposphere, ozone has a lifetime of 5 months and is increasing by 2-1% per year. Ozone is responsible for 3% of the total global warming (Gawell, 1989).

Research suggests that ozone, either alone or in combination with nitrogen dioxide and sulphur dioxide, may responsible for up to 90% of United State crop losses resulting from air pollution (Heck, *et al*., 1982). Research by Wahid *et al*., (1995), was had been used open top chambers ventilated with ambient and charcoal filtered air in the vicinity of Lahore, Pakistan demonstrated the reductions of 42% and 37% in the grain of two cultivars of rice (*Oryza Sativa L.*). Rapid urbanization, with the associated growth in industry and transportation systems, has increased regional concerns with regard to emissions of sulphur dioxide (SO_2) and nitrogen oxides (NOx). Motor vehicles are one of the most intensively regulated sources of NOx and VOCs that are precursors to the formation of tropospheric O_3. Meteorological factors such as high solar radiation and temperature also contribute a crucial influence of ozone formation. So, equator countries that have a warm and humid tropic must be concern because they have a high risk to increase the ozone formation including Malaysia.

Ozone damage to plants can occur without any visible signs. Many farmers are unaware that ozone is reducing their yields. Ozone enters the plant's leaves through its gas exchange pores (stomata), just as other atmospheric gases do in normal gas exchange. It dissolves in the water within the plant and reacts with other chemicals, causing a variety of problems.

However, the effect of ozone on crop yield in developing countries was very limited. Determination of critical O_3 levels for agricultural crops, natural vegetation and forest trees have been derived on the basis of the results obtained from field (mainly open top chamber) experiments with realistically elevated O_3 concentrations. At the European work programme under the UNECE (United Nation Economic Commission for Europe), critical O_3 levels for agricultural crops are expressed as

AOT40 (cumulative exposure over the threshold concentration of 40 ppb (part per billion)).

Therefore, this study proposes to determine the growth and physiological response of rice plant due to ambient ozone concentration in the field. And all above is to determine the yield reduction due to elevate ozone concentration.

1.1 Hypothesis of the Study

$H_0 = (\mu_1 - \mu_2) = 0$ (no difference between filtered and non filtered plant)

$H_a = (\mu_1 - \mu_2) \neq 0$ (filtered and non filtered plant are different)

Where:

μ_1 and μ_2 are the mean data of filter and non filter plant, respectively.

1.2 Objective of the Study

1. To determine the physiological and growth responses of rice plant to ambient ozone stress.
2. To determine the impact of ambient ozone stress on yield

1.3 Significant of the Study

The result from this study will show the effect of ozone to yield of rice. The results also provide impact of ozone on the physiological process and growth performance of rice plant. Despite these important study findings, there is a large discrepancy in the number of studies in developed and developing countries of crop yield losses due to ozone, and it is clear that significant of ozone pollution has been poorly recognized in developing countries. But there are very limited literatures available on developing country especially in Asia, so this study can be recorded as a reported yield reductions linked to ambient ozone concentration in developing countries.

The output could be used by farmers, local, state and regional authorities departments for decision-making aimed at preventing or reducing adverse impact on rice production due to pollutant concentration especially ozone.