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KATA PENGANTAR

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Kami selalu berusaha untuk dapat menerbitkan jurnal ini tepat waktu sesuai dengan rencana. Kepada biologiwan dan peminat biologi terutama anggota Perhimpunan Biologi Indonesia, diharapkan untuk berpartisipasi dalam mengisi penerbitan berikutnya.

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Penyunting

PHOTOSYNTHESIS AND YIELD OF WHEAT GROWN UNDER DIFFERENT TEMPERATURE REGIMES

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ABSTRACT

PHOTOSYNTHESIS AND YIELD OF WHEAT GROWN UNDER DIFFERENT TEMPERATURE REGIMES. AGUS KARYANTO. Response of maturing plants to high temperature stress may be determined by shoot/root interactions that mediate senescence. This study elucidated the photosynthesis and yield of wheat (*Triticum aestivum* L.) under different shoot/root temperatures. Plants were subjected to 22/22°C, 22/32°C, 32/22°C, and 32/32°C shoot/root regimes from 7 day after anthesis until they matured. Viable leaf area was greatly reduced by high root temperature at high or low shoot temperature. Photosynthesis, stomatal conductance, and chlorophyll variable fluorescence were decreased more by high root than by high shoot temperature. High root temperature promoted senescence and less grain yield. Low grain mass under high shoot/root temperature was caused by small seed size due to short grain-filling duration and inadequate photosynthate. In conclusion, root temperature is involved in shoot senescence, which in turn may regulate photosynthate partitioning and grain development.

Key words: Shoot/root temperatures, wheat, photosynthesis.

ABSTRAK

FOTOSINTESIS DAN HASIL GANDUM PADA BERBAGAI KISARAN SUHU TUMBUH, AGUS KARYANTO. Respons terhadap stres suhu tinggi pada fase reproduktif tanaman ditandai dengan cepatnya proses penuaan. Penelitian ini bertujuan untuk mengetahui laju fotosintesis dan hasil tanaman gandum (*Triticum aestivum* L.) yang tumbuh pada berbagai macam suhu tajuk/akar. Perlakuan suhu tajuk/akar 22/22°C, 22/32°C, 32/22°C, dan 32/32°C dimulai 7 hari setelah anthesis sampai matang fisiologis. Luas daun sangat berkurang akibat tingginya suhu akar, dan ini terjadi baik pada suhu tajuk yang tinggi maupun rendah. Penurunan laju fotosintesis, konduksi stomata, dan variabel iluminasi klorofil lebih banyak disebabkan oleh perlakuan suhu tinggi pada akar daripada perlakuan suhu tinggi pada tajuk. Suhu tinggi mempercepat proses

penuaan dan menurunkan hasil biji. Rendahnya hasil biji pada perlakuan suhu tajuk/akar yang tinggi disebabkan oleh kecilnya ukuran biji akibat pendeknya masa pengisian biji dan terbatasnya fotosintat. Suhu akar ternyata erat kaitannya dengan proses penuaan tajuk, yang pada akhirnya dapat mempengaruhi pendistribusian fotosintat dan perkembangan biji.

Kata kunci: Suhu tajuk/akar, gandum, fotosintesis.

INTRODUCTION

Photosynthate production by wheat leaves depends on the rate of photosynthesis, viable leaf area, and duration of leaf function (Simmons, 1987). Peak net photosynthesis per unit area usually occurs after leaves reach maximum area (Rawson *et al*., 1983). Under stress conditions, current photosynthate supplies decrease and plant must rely on previously stored assimilates for grain filling (Simmons, 1987).

High temperature affects photosynthate production greatly by decreasing photosynthesis and leaf longevity and increasing respiration (Wardlaw *et al*., 1980). Stress from high temperature during reproductive development may decrease grain-filling period and yield. Response of wheat to high temperature, whether of shoots or roots, is signaled by acceleration of senescence, which is probably mediated by roots during grain filling (Kuroyanagi and Paulsen, 1988). Low root temperature was interpreted as protective effects on high temperature injury to shoots (Chaisompongpan *et al*., 1989).

Adverse effects of high temperature on photosynthate production and the apparent importance of photosynthate partitioning on root and shoot responses prompted the present study. Objectives were to ascertain photosynthetic rates and their relationship to partitioning of photosynthate under different shoot/root temperature regimes during reproductive period of wheat.

MATERIALS AND METHODS

Experiment was conducted at Agronomy Department, Kansas State University, Manhattan, Kansas, USA. Hard red spring wheat cultivar Len plants were hydroponically grown in pots, inside growth chambers, containing Hoagland solution (Hoagland and Arnon, 1950). The solution was adjusted to pH 5.0 semiweekly and replaced weekly and supplied with continuous aeration. Photoperiod was 16-hour day/8-hour night. Light intensity was 420 μmol m^{-2} s^{-1} PAR (Photosynthetically Active Radiation). Relative humidity was 40-50% during the day and 60-70% during the night, and temperature was 22/17°C day/night up to 7 day after anthesis.

Started at 7 day after anthesis plants were randomly distributed among controlled environment chambers with four temperature regimes until they matured. Shoot/root treatments of 22/22 and 32/32°C were set by the air temperature of the chambers. Shoot temperatures for 22/32 and 32/22°C were also set by the air temperature, and differential root temperature were obtained by immersing plant containers in large tank of water at the desired temperature. With 22°C air, 32°C root temperature was maintained by heating the tanks on large hot plates, and with 32°C air, 22°C root temperature was maintained by refrigerated circular coils inside the tanks. Root temperatures were controlled by a Thermistemp Temperature Regulator (Model 64, YSI Co., Inc Yelow Spring

Ohio), and shoot and root temperatures were monitored hourly by a 24-point thermograph.

The rate of photosynthesis, stomatal conductance, and internal CO_2 concentration of flag leaves were measured at weekly interval by means of Portable Photosynthesis System LI 6200 (Li-Cor, Lincoln, Nebraska). Atmospheric CO_2 during measurement was 360 to 380 µL L^{-1} , relative humidity was 40%, and irradiance was above 420 µmol photon m^{-2} s^{-1} . Chlorophyll fluorescence was measured on dark-adapted flag leaves by using Fluorometer SF 20 (Richard Brancker Res., Ltd., Ottawa, Canada). Initial (Fo), maximum (Fm), and final fluorescence were recorded, and chlorophyll variable fluorescence (Fv) was calculated as the difference between maximum and initial fluorescence.

The area of viable leaves, which were selected visually on the basis of color, was measured with a LI 3000/3100 meter (Li-Cor, Lincoln, Nebraska). Samples for grain mass was also taken at weekly interval from 7 to 35 day after anthesis.

RESULTS AND DISCUSSION

Results of this study suggest direct roles for roots in monocarpic senescence at normal temperature and in accelerated senescence at elevated temperature. The area of viable leaves decreased slowest during maturation when both shoot and root temperatures were low (Fig. 1). Increasing the shoot temperature to 32°C accelerated loss of leaf area, but high root temperature was considerably more injurious and caused viable leaves to senesce quickly.

Photosynthetic rates of plants grown with low shoot/root temperature, 22/22°C, were high and declined only slightly during maturation (Fig. 2). Increasing the shoot temperature (32/22°C) lowered photosynthesis slightly, but rates were still high when plants matured. High root temperature (22/32°C) was more injurious than high shoot temperature to photosynthesis, and no activity was detected after 35 day. Combining high shoot and high root temperature (32/32°C) was most damaging, and activity declined steadily to undetectable levels after 28 day.

Stomatal conductance separated distinctly into two regimes. Conductance was high when root temperature was low and was low when root temperature was high (Fig. 2). Internal CO_2 concentration differed little among temperature treatments or sampling date (Fig.2).

Chlorophyll variable fluorescence (Fv) was nearly stable and diminished only slightly from the first to the last dates in plants grown at 22/22°C (Fig. 3). Warming either the shoots or the roots to 32°C decreased Fv similarly until the last date, when Fv fell markedly in plants with high root temperature. The ratio of variable/maximum fluorescence (Fv/Fm) declined concomitantly with the decline in Fv. The decline in Fv as well as Fv/Fm resulted from a marked reduction in the level of Fm along with a slight increase in the yield of Fo (data not shown). The decline in the photosynthetic rate and variable fluorescence likely resulted from ultrastructural changes in the chloroplast of senescing leaves during high temperature stress (Mae *et al.*, 1987). High stomatal conductivity of plant grown with low root temperature undoubtedly was necessary for the high photosynthetic rates that were observed and, by delaying senescence, may have prolonged leaf viability.

Grain growth after anthesis responded favorably to low temperatures and adversely to high temperature when shoot and root were under the same temperature regimes (Fig 4). Holding shoots and roots at 22°C maintained high mass of grain. High shoot/root temperature was only slightly more damaging than high root temperature alone. Large grain mass at 22/22°C can be attributed to the high rate of photosynthesis and long duration of leaf function. The 32/32°C regime had an opposite effect. Hastening leaf senescence by high shoot/high root temperature was also observed as decreasing variable fluorescence. High temperature probably caused low root activity and slowed synthesis of cytokinin in root and translocation of cytokinin to shoots (Kuroyanagi and Paulsen, 1989), which induced senescence of leaves and cessation of grain development (Herzog, 1982).

Investigations of high temperature injury to plants have mostly emphasized effects on photosynthetic sources and reproductive sinks (Al-Khatib and Paulsen, 1990; Chowdhury and Wardlaw, 1978). The present results demonstrate that response of roots to high temperature should also be considered. The data indicate that plant injury by high temperature is influenced by high root temperature as well as high shoot temperature. Root (soil) temperature is lower than that of shoot (air) temperature during the reproductive period of wheat but might be high enough to augment injury. The root temperature might be involved in shoot senescence and be indirectly regulate photosynthate partitioning and grain yield. It is not clear, however, that roots mediate plant response to high temperature, although it seems apparent that their role is as important as those of shoots and spikes in wheat (Kuroyanagi and Paulsen, 1988). More importantly, perhaps, is the possibility that root temperature might be modified more easily than air temperature. Ground cover, tillage, irrigation, and other cultural practices affect soil temperature, whereas few if any methods are practical for manipulating air temperature (Cooper, 1973; Nielsen, 1974).

In conclusion, shoot senescence which reduced the rate of photosynthesis and its related activities and, hence, the photosynthate supply to the grain is more affected temperature of the root than that of the shoot.

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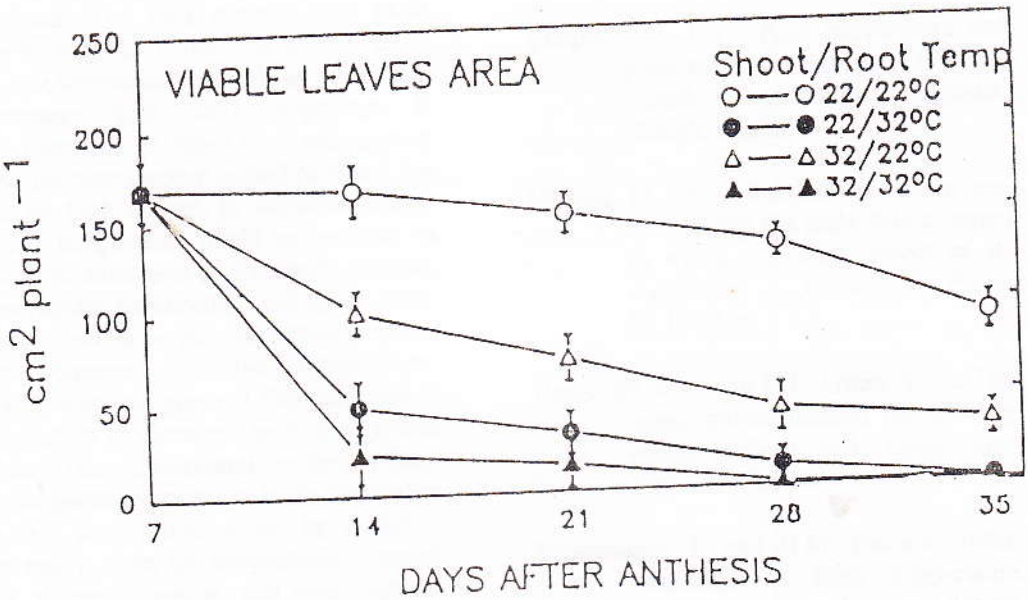

Figure 1. The area of viable leaves of wheat plants grown under four shoot/root temperature regimes after anthesis. Vertical lines are ± SE; lines that are not shown are shorter than symbols.

Gambar 1. Luas daun tanaman gandum yang tumbuh pada empat macam suhu akar/tajuk setelah penyerbukan. Garis vertikal adalah ± SE; garis yang tidak nampak lebih kecil daripada simbol.

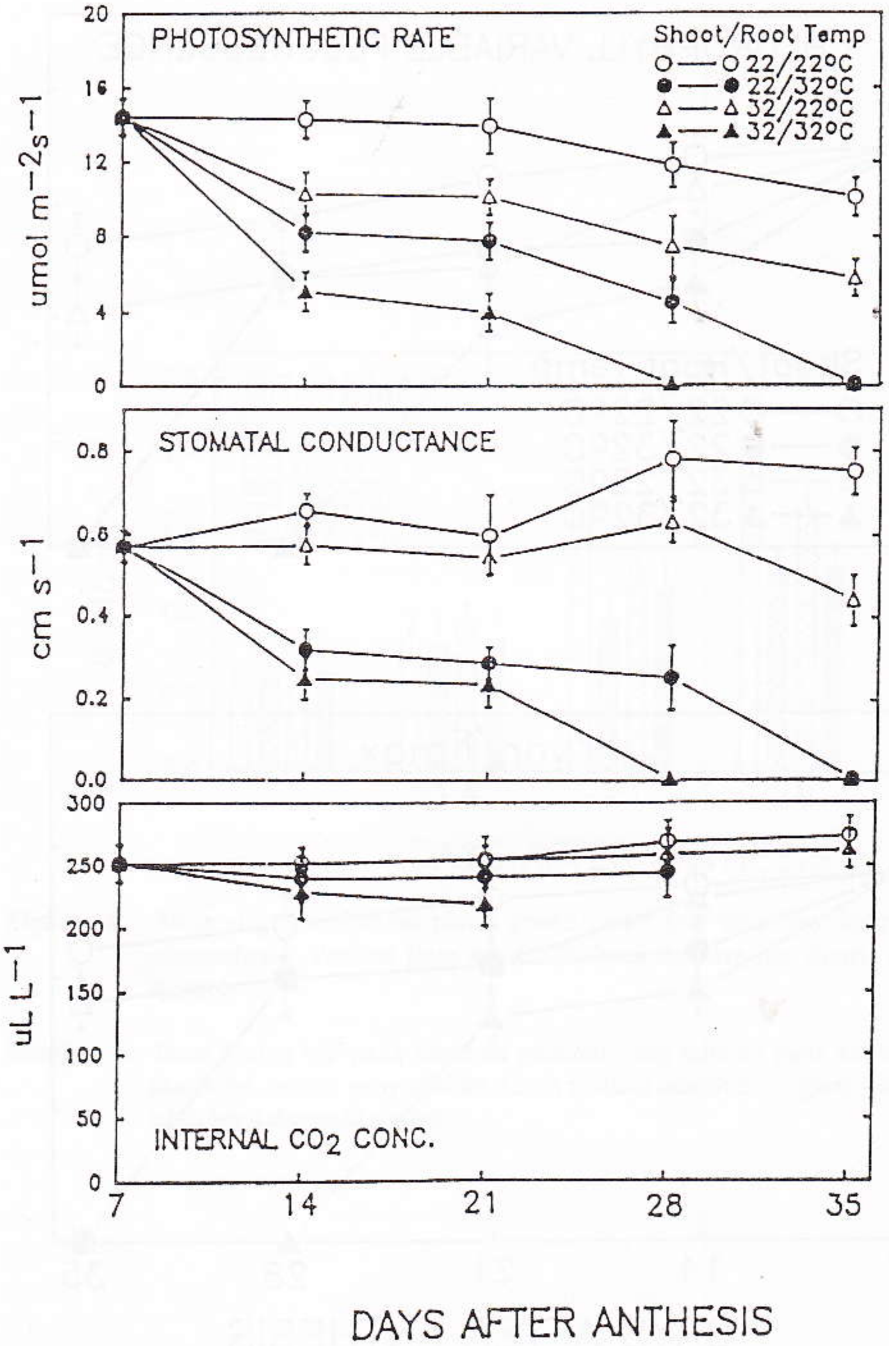

Figure 2. Photosynthetic rate, stomatal conductance, and internal CO_2 concentration of wheat plants grown under four shoot/root temperature regimes after anthesis. Vertical lines are ± SE; lines that are not shown are shorter than symbols.

Gambar 2. Laju fotosintesis, konduksi stomata, dan kadar CO_2 dalam daun tanaman gandum yang tumbuh pada empat macam suhu akar/tajuk setelah penyerbukan. Garis vertikal adalah ± SE; garis yang tidak nampak lebih kecil daripada simbol.

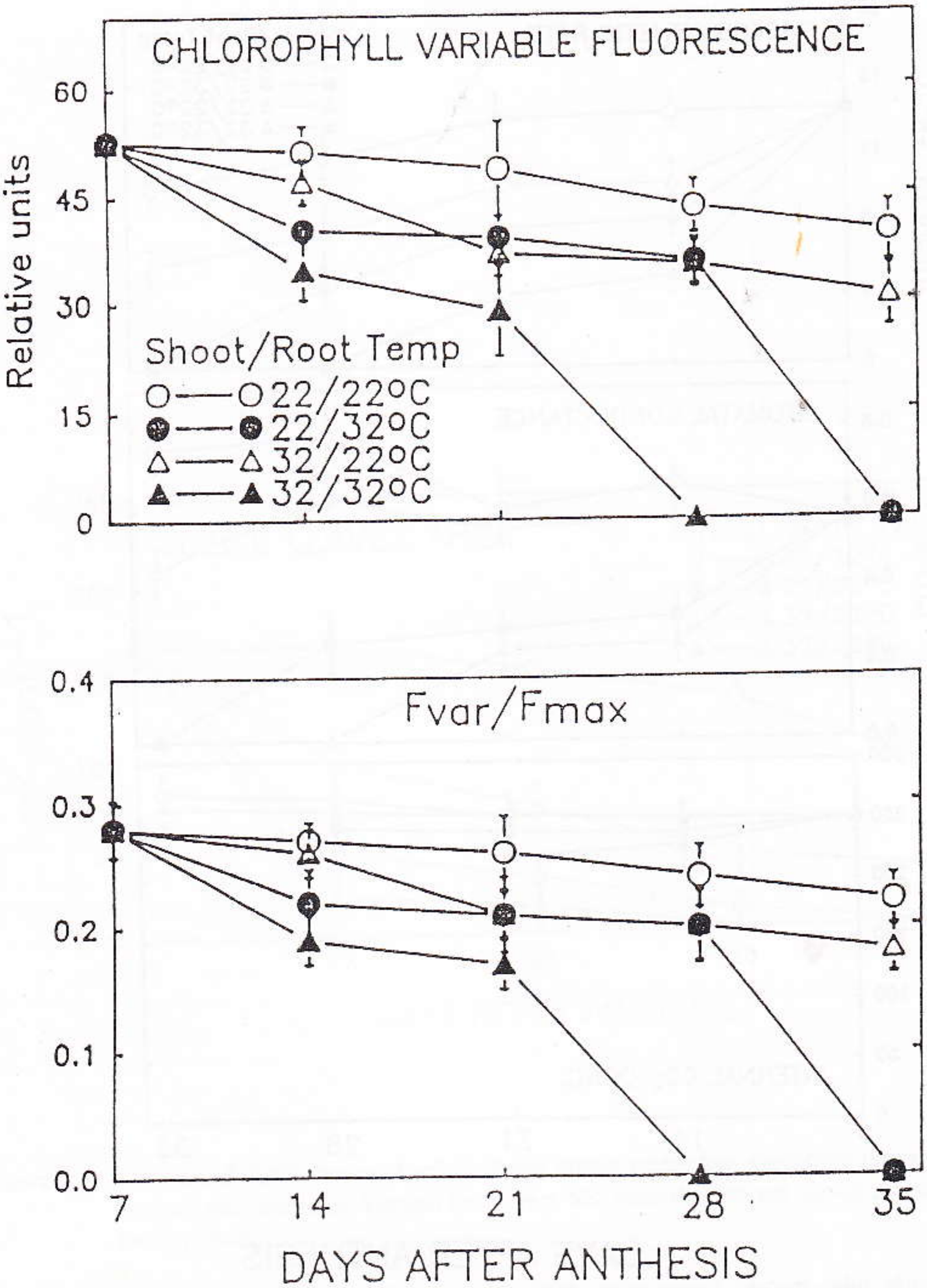

Figure 3. Chlorophyll variable fluorescence (Fv) and ratio of Fv/Fm of wheat plants grown under four shoot/root temperature regimes after anthesis. Vertical lines are ± SE; lines that are not shown are shorter than symbols.

Gambar 3. Variabel iluminasi klorofil (Fv) dan nisbah Fv/Fm pada tanaman gandum yang tumbuh pada empat macam suhu akar/tajuk setelah penyerbukan. Garis vertikal adalah ± SE; garis yang tidak nampak lebih kecil daripada simbol.

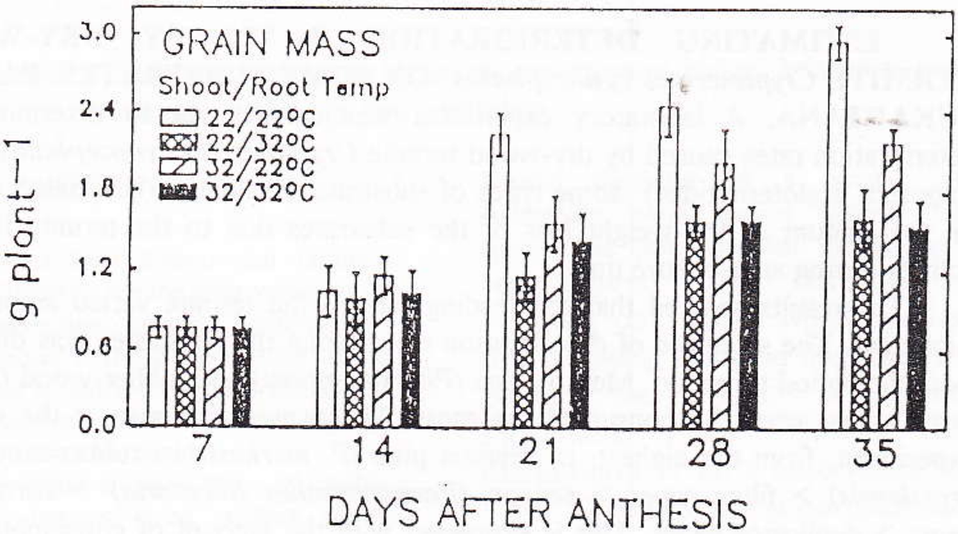

Figure 4. Mass of grain of wheat plants grown under four shoot/root temperature regimes afteranthesis. Vertical lines are ± SE; lines that are not shown are shorter than symbols.

Gambar 4. Berat kering biji pada tanaman gandum yang tumbuh pada empat macam suhu akar/tajuk setelah penyerbukan. Garis vertikal adalah ±SE; garis yang tidak nampak lebih kecil daripada simbol.