The Effect of Air Temperature on the Dark Respiration and Nutrient Absorption of C_3 and C_4 Crop Species

By NGUYEN QUOC VONG and YOSHIO MURATA

Faculty of Agriculture, University of Tokyo

Dry matter production of plants is the processes of organic substance formation by the plant from carbohydrates, the end products of photosynthesis, and from a small quantity of inorganic substances absorbed by roots from the soil. Photosynthetic products are needed for the growth of plants both as growth material and as substrate for respiration, and stimulate the process of salt absorption directly and indirectly in several ways. Thus, when growth factors and translocation processes are not limiting to the dry matter production, the quantity and quality of the dry matter produced will be determined by the level of the three physiological processes, photosynthesis, respiration, nutrient absorption as well as factors in morphological characteristics and their relationships.

There is clear evidence for the existence of difference among C_3 and C_4 crop species in the rate of dry matter production[1,3,9], and according to recent studies of Japanese IBP, it is clear that air temperature (ambient temperature) and solar radiation are the two most influential factors which affect the dry matter production of crops in various regions of Japan[5]. Therefore, it may be quite significant to make clear how the air temperature and solar radiation will affect photosynthesis, respiration and nutrient absorption which have fundamental connection with dry matter production and growth of plants.

From the above-mentioned point of view, the authors carried out a series of research to make clear what influence the air temperature and solar radiation would give upon the growth of plants through their effects upon the above-described basic physiological processes and morphological characteristics of some C_3 crop species, i.e., rice, soybean, wheat, barley and pea, and C_4 species, i.e., maize, sorghum, millet and barnyard millet, each cultured under its optimum temperature. Some of the major results were reported elsewhere[8,9,10]. The present paper will discuss only the effect of air temperature on the dark respiration and nutrient absorption of the C_3 and C_4 crop species.

Effect of air temperature on dark respiration

The effect of temperature on dark respiration is shown in Fig. 1 where it is seen that dark respiration rate increases steadily and exponentially with increasing temperature in all the 9 species alike. However, interestingly enought, the level of dark respiration rate is clearly different from species to species: more vigorous in C_4 species than in C_3 species at all of the 6 levels of temperature as shown in Fig. 1. The mean respiration rate of the C_4 species was 2.8 times, and the C_3 winter crops, 1.4 to 2.3 times, greater than that of the C_3 summer crops.

As for the effect of air temperature on the dark respiration of various species, Murata and Iyama[6], Murata et al.[7] reported that the dark respiration rate of 20 forage and grain crops increased with increasing air temperature with little specific differences. However,

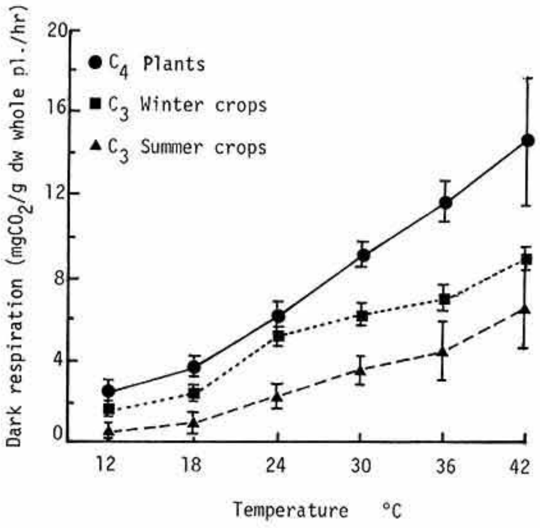

Fig. 1. Relationship between dark respiration and temperature in 3 groups of crop species. The vertical bars show the standard error

Imai et al.[2] who compared various photosynthetic properties of 9 species found that dark respiration rate at 30°C tend to be higher in some C_4 species than in C_3 species. Also, Maeno[4] reported that the rate of respiratory consumption of dallisgrass (C_4) was higher than that of Italian ryegrass (C_3) during their regrowth period.

Effect of air temperature on nutrient absorption

As for the effect of temperature on the nutrient absorption by root, a number of studies have been reported with various plants. From these studies, it is clear that there is the optimum temperature for nutrient absorption in each species. However, there are very few works which have compared the temperature response of nutrient absorption among different species under the same conditions, except for the study of Worley et al.[11].

In the present study, therefore, 9 species of these two plant types were used to compare their optimum temperature for nutrient absorption. As a result, it was found that the absorption rate of NH_4-N, P and K generally tends to increase with increasing temperature until a maximum value is reached, and then to decrease again at higher temperatures. These optimum temperatures for absorption were different among species and also among the three nutrient elements.

As shown in Fig. 2, the optimum temperature for the absorption of NH_4-N, P and K in rice was 36–42°C, 36°C and 42°C or higher,

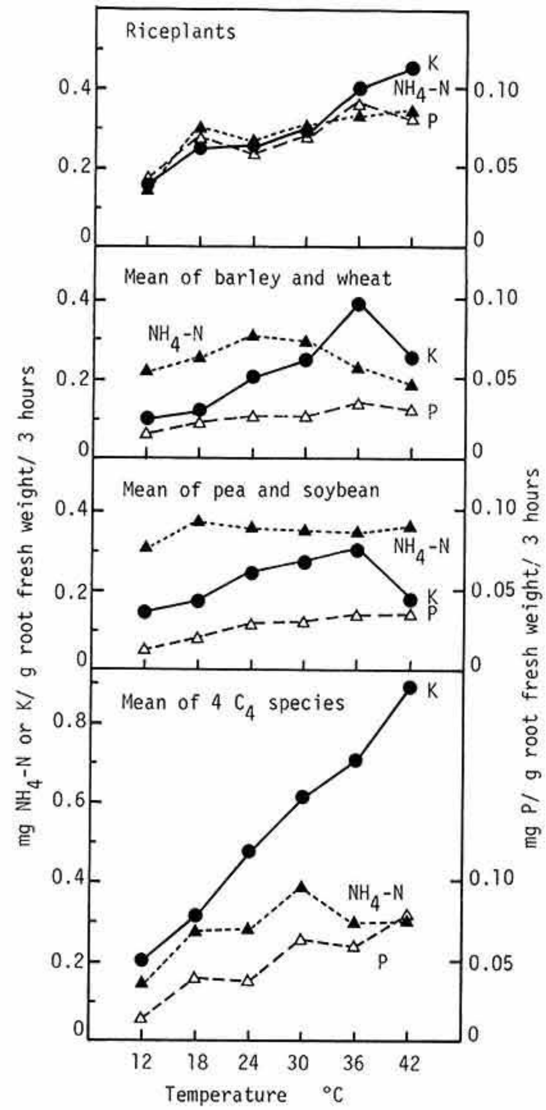

Fig. 2. Relationship between temperature and NH_4-N, P, K absorption in various groups of crop species

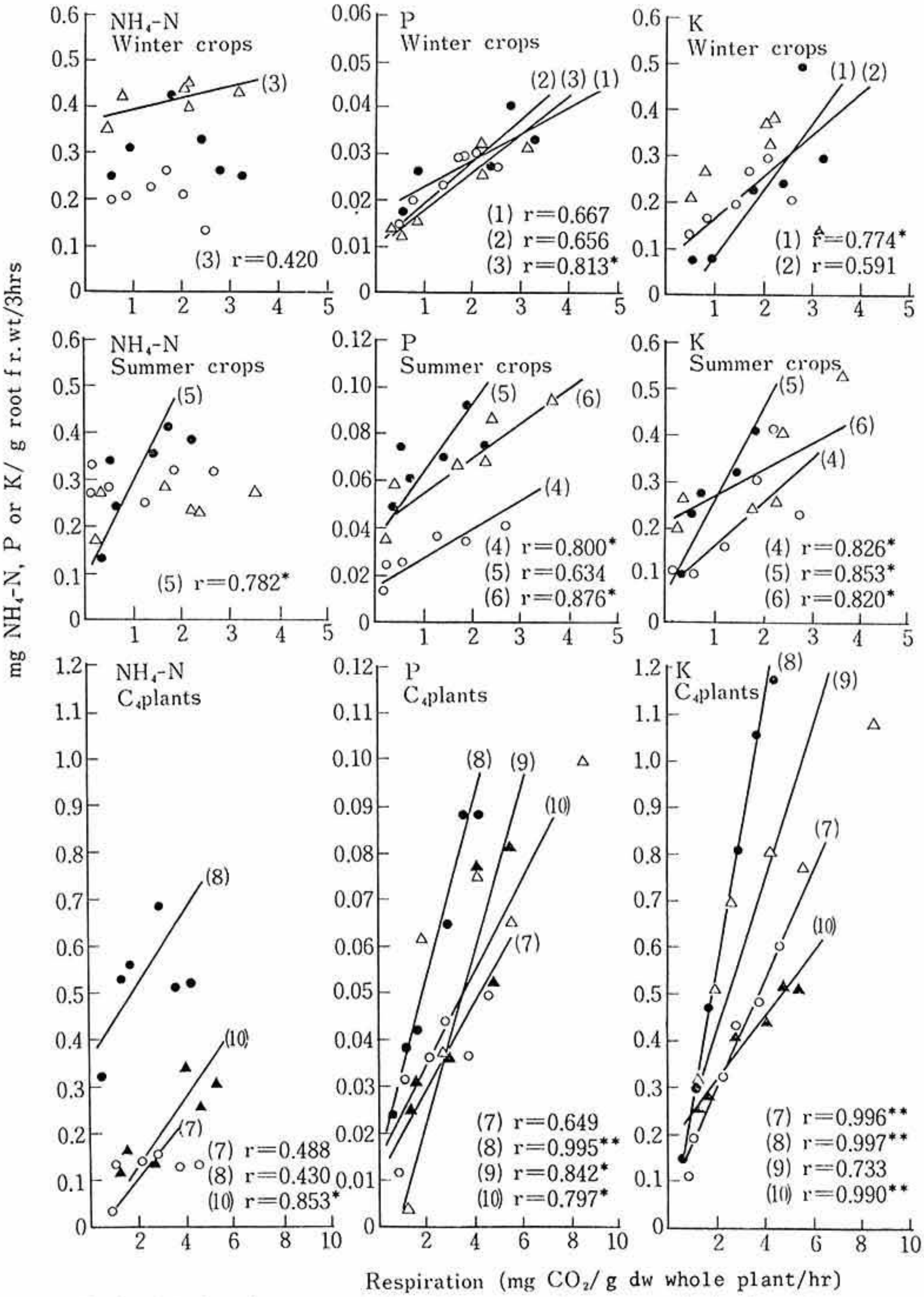

Fig. 3. Relationship between NH_4-N, P, K absorption and respiration in various crop species. Numerals in parenthesis indicate crop name, i. e., (1) wheat, (2) barley, (3) pea, (4) soybean, (5) rice, *indica*, (6) rice, *japonica*, (7) maize, (8) sorghum, (9) millet, and (10) barnyard millet.

respectively. In soybean and pea, that for P and K was 36–42°C and 36°C, respectively, while that for NH_4-N was not recognized at all. In wheat and barley, that for NH_4-N was 24°C and that for both P and K was 36°C. In the C_4 species, the optimum temperature for NH_4-N absorption was 30°C and both for P and K was 42°C or higher for all the 4 C_4 species. Interestingly, K absorption in this type of plants increased linearly with increasing temperature attaining as high as 1.2 to 4.7 times that in the C_3 species. The higher rate of K absorption by the C_4 species as compared with the C_3 species was in line the result of Worley et al.[11] who found that the rate of K absorption was higher in sudangrass, a C_4 species, than in rye, pea or soybean, C_3 species.

Relationship between dark respiration and nutrient absorption

Relationships between dark respiration and nutrient absorption are shown in Fig. 3. In this figure, although the correlation of dark respiration rate with NH_4-N absorption is not so close, that with P and K absorption is very close in all the species. This may be taken as a proof to show that nutrient absorption by the root is heavily dependent on the respiratory activity of the whole plant. In addition, it was found by comparing the regression lines that the efficiency of respiration in absorbing nutrients, especially K, is higher in the C_4 species than in the C_3 species. Thus, it was made clear for the first time in the present study that at higher temperatures C_4 species can absorb more nutrients with higher respiratory efficiency than C_3 species.

Conclusion

Cultivated under the optimum growth temperatures, the effect of air temperature on the dark respiration is similar in both C_3 and C_4 species, increasing exponentially with increasing temperature. However, the level of dark respiration in the C_4 species is very high in the whole temperature range as compared with that of the C_3 summer species, the C_3 winter species showing medium values. The reason and ecological significance, however, remains to be proved.

As for the effect of temperature on the nutrient absorption by root, evidence was obtained to show that the optimum temperature for nutrient absorption is different among both species and nutrient elements. Further, NH_4-N, P and K absorption was found to be very closely correlated with dark respiration rate in their response to temperature. In the C_4 species, the efficiency of respiratory process to absorb nutrients was higher at high temperatures than in the C_3 species. This may be one of the basis for the adaptation of C_4 species to high temperature environment, and their extremely high rate of K absorption is quite interesting from the importance of this element in plant metabolism, although its exact role is still not clearly understood.

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