Studies on the Photosynthesis of Forage Crops

IV. Influence of air-temperature upon the photosynthesis and respiration of alfalfa and several southern type forage crops.

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In the previous study using 12 species²⁾, it was found that most of the 'northern type' forage crops showed their highest photosynthetic activity at 10-15°C, while 'southern type' grasses, bahia-grass and bermudagrass, showed their highest value at a far higher temperature, about 35°C.

In this paper, not only the short-term, but also comparatively long-term, influences of temperature upon photosynthesis and respiration were compared using eight more species, most of which, except for alfalfa, belong to southern type forage crops.

MATERIALS AND METHODS

The following eight species were used: alfalfa (var. Ranger), Rhodesgrass (var. Rongoi No. 260), dallisgrass, teosinte, Sudan grass, new sorgo, maize (dent corn, var. Kō No. 7), and barnyardgrass (*Echinochola crus-galli*, Beauv. var. *caudata*, Kitagawa).

Seedlings of these species were soil-cultured in small pots for 30 to 50 days in a glass house. Their photosynthetic and respiratory rates were measured by the same method and apparatus (an open system installed with Beckman's IRGA, Model 15A) as in the previous paper¹⁾, under a constant light intensity of 40 klux, atmospheric CO₂ conc. and gradually changing temperature from 15° to 50° and 20° to 0°C. CO₂ correction was made to the observed values as before²⁾ to get photosynthetic values corresponding to 300 ppm CO₂.

RESULTS

1. Short-term influence of temperature upon photosynthesis

The short-term influence of temperature upon the apparent photosynthesis and respiration of eight species was compared in figures 1 to 4.

The temperature-photosynthesis (true) curves for respective crops were synthesized from these figures and they were directly compared in fig. 5.

The following points are recognizable in fig. 5: The optimum range of temperature for the photosynthetic activity (p_0) of alfalfa, a northern type species, is comparatively low and wide, 5-30°C, showing its highest activity at 10-20°C, as were the cases of orchard grass and ladino clover²⁾. On the other hand, such southern type species as Sudan grass, new sorgo, teosinte, dallisgrass and maize show considerably higher optimum range, 20-40°C. As for Rhodesgrass, also a southern type species, reaches its highest p_0 value at about 35°C as were the cases of bahiagrass and bermudagrass²⁾. Barnyardgrass is very interesting in that it shows the highest p_0 value in the widest range of temperature among the species tested.

When, in the next place, both the present re-

Fig. 1. Influence of temperature upon apparent photosynthesis (AP) and respiration (R) of alfalfa and Rhodesgrass.
AP, R: mg CO₂/100cm², hr

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Fig. 2. The cases of dallisgrass and teosinte.

Fig. 3. The cases of Sudan grass and new sorgo.

sults dealing with 8 species and the previous ones dealing with 12 species were considered together, it was found that the temperature-photosynthesis curves of the 20 species can be classified into six groups, as is shown in fig. 6, by the position and width of the optimum range.

According to this classification, the so-called northern type species are found in the groups I, II and III, showing low optimum temperatures for photosynthesis. Among them, those belonging

Fig. 4. The cases of maize and barnyardgrass.

to the group III which is featured by the broadness of its optimum range, show a wide, ecological distribution from the north to south. Also in the southern type species which belong to the group IV, V or VI and show a high optimum temperature for photosynthesis, the same tendency is found: those belonging to the group IV or VI show a wider ecological distribution than those belonging to the group V. For example, dallisgrass (group IV) is more resistant to cool weather and more widely distributed than bahiagrass or bermudagrass. As for barnyardgrass (group VI), it is quite widely distributed in Japan from the north to south.

From these, it may be concluded that the position and range of the optimum temperature for photosynthesis of crop plants are quite closely correlated with the empirical, optimum temperature for their growth and ecological distribution.

2. Short-term influence of temperature upon respiration

From the temperature-respiration curves in figs. 1 to 4, it is apparent that there is little difference seen among the species in the response of respiration to temperature, although the rate

Fig. 5. Comparison of the temperature-photosynthesis curves of eight species.

P_0 : 'True' photosynthesis, mg CO_2 /100 cm^2 , hr

of respiratory increase, Q_{10} value, is not always equal among the species. These results are quite in accordance with the previous ones²⁾.

3. Long-term influence of temperature upon photosynthesis and respiration

In the previous study, some difference was observed in the response of photosynthesis to temperature between winter-grown seedlings and summer-grown ones of orchard grass or perennial ryegrass²⁾. In order to examine the phenomena under more strictly controlled conditions, seedlings of 5 species were placed for 10 days in growth chambers (Koitozon) kept at 25°, 20° and 15°C and in an ordinary glass house, respectively, and afterwards their responses of photosynthesis and respiration to temperature were compared with one another.

Although, as shown in figs. 7 and 8, the seedlings that had been kept in growth chambers showed, without exception, somewhat lower photosynthetic activity throughout the whole temperature range than those kept in the glass house, little difference is seen in the shape of the temperature-photosynthesis, as well as the temperature-respiration, curves in all the species tested.

From these results it may be concluded that treatment of such an extent as keeping seedling at different temperatures for ten days does not bring about any noticeable change in their temperature-photosynthesis, and-respiration, relationships.

4. Comparison of maximum photosynthetic values among species

In the previous study²⁾, it was found that

bahiagrass and bermudagrass showed quite high maximum photosynthetic values, more than twice the ordinary land plants. In the present study, Rhodesgrass and barnyardgrass were found to have quite high values, more than 35 mg and 40 mg of CO_2 , respectively, and it was confirmed that maize shows high activity, though the observed value was not so high as originally reported³⁾⁴⁾. Compared at each optimum temperature, southern type species show generally a higher activity than northern type ones among which alfalfa was the highest.

DISCUSSION

The growth response of plants to temperature is quite different from species to species and it is possible that the effect of temperature is mediated by its influence on photosynthesis and, therefore, on carbohydrate supply. According to the results of previous and present studies the range of optimum temperature for photosynthesis of a given species has quite an intimate, relationship with the empirical, optimum temperature for growth of the same species. However, this does not imply that the above-mentioned possibility has been testified. Because, the temperature-photosynthesis curves are far flatter in their shape than usually found temperature-growth curves. This means that, though individual species which are different in their origin are so made as to display their full photosynthetic acti-

Fig. 6. Classification of the temperature-photosynthesis curves in 20 species.

I: Common vetch. II: Barley, naked barley, wheat, rye, Italian ryegrass, perennial ryegrass, Chinese milk vetch. III: Orchard grass, ladino clover, alfalfa. IV: Sudan grass, dallisgrass, teosinte, new sorgo, maize. V: Bahiagrass, bermudagrass, Rhodesgrass. VI: Barnyardgrass.

Fig. 7. Influence of temperature upon the photosynthesis (p_0) and respiration (r) of alfalfa and dallisgrass after being kept at different temperatures for ten days.

G: Material kept in an ordinary glass house
25, 20, 15: Material kept in a phytotron set at 25°, 20°, and 15°C, respectively, under natural light.

vity at around the empirical, optimum temperature for their growth, some other factors, more directly related to the growth processes, should be sought as a responsible factor for growth retardation usually observed outside the optimum temperature.

SUMMARY

The short-term influence of temperature on photosynthesis and respiration was compared among eight species mainly of southern type forage crops. Comparatively long-term influence of temperature was also tested. Seedling plants were used in both cases. The results are as follows:

1) The photosynthesis of alfalfa, a northern type species, reached its highest activity at 10–25°C, while dallisgrass, Rhodesgrass, teosinte, new sorgo, maize, Sudan grass, and barnyardgrass which belong to the southern type species showed their highest activity at 25–40°C.

2) In contrast to this, there is little specific difference seen in their respiratory response to temperature.

3) The temperature-photosynthesis, and -respiration, relationships did not show any material

Fig. 8. Influence of temperature upon the photosynthesis and respiration of teosinte, Sudan grass and new sorgo after being kept at different temperatures for ten days.

difference after the seedlings were kept at different temperature for ten days.

4) It was concluded that the optimum temperature for photosynthesis has quite an intimate relationship with the empirical, optimum temperature for the growth and ecological distribution of individual species.

5) Rhodesgrass and barnyardgrass showed quite high maximum photosynthetic values, nearly twice the value for ordinary land plants.

LITERATURE CITED

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〔和 文 摘 要〕

飼料作物および牧草の光合成に関する研究

第4報 アルファルファおよび数種の南方型飼料作物の光合成,
呼吸作用に及ぼす温度の影響

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前々報に引き続いて、南方型を主とした8草種につき、光合成、呼吸作用に及ぼす短時間の温度の影響を比較し、さらにある程度長期間の温度の影響をみるために、30—50日の幼植物を用いて実験を行ない次の結果を得た。

1) 北方型のアルファルファの光合成はラジノクローバーとほぼ同じく、10—25°Cにおいて最大値を示したが、南方型のダリスグラス、テオシント、ローズグラス、ニューソルゴー、トウモロコシ、スーダングラスおよびケイヌビエは25—40°Cにおいて最大値を示した。

2) これに対し呼吸作用の温度に対する反応には種間に差が見られず、0—45°Cの範囲では温度の上昇に伴って指数関数的に上昇した。

3) 上のような温度—光合成関係は、材料植物を異なる温度(15°, 20°, 25°Cの昼夜定温の人工気象室)に10日間おいた程度ではほとんど変化しなかった。

4) 前々報の結果と合せて、20草種の光合成の適温は北方型では低く南方型では高く、その生態的な生育適温および分布と密接な関係をもつと結論された。

5) ローズグラスおよびケイヌビエは普通の陸上植物の光合成の2倍に近い能力をもつことが見出された。