DIFFERENCES IN LEAF PHOTOSYNTHESIS AND LEAF TRANSPIRATION RATES AMONG SIX COMMERCIAL WHEAT VARIETIES OF WEST PAKISTAN*

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Synopsis. Mexi-Pak, a modern high yielding semi-dwarf whert variety with high response to fertilization showed higher photosynthetic rate and higher transpiration rate per unit leaf area as compared with old Pakistani varieties. High photosynthetic rate was associated with high transpiration rate, high specific leaf weight and high nitrogen content per leaf area. Percentage of leaf nitrogen content to leaf dry matter was also high in Mexi-Pak.

Introduction

Differences in photosynthesis of single attached leaves in intense light and 300 ppm CO₂ have been observed among cultivated wheats and its wild relatives including diploid, tetraploid and hexaploid species having spring and winter habits of growth (KHAN and TSUNODA, 1970ac). It was reported that the wild species in general and wild diploid species in particular, having "thick" and small leaves, showed higher photosynthetic rates per unit leaf area as well as higher nitrogen content in comparison to "thin" and large leaves of cultivated tetraploid and hexaploid species which showed a lower nitrogen content and lower photosynthetic rate per leaf area. However, this low nitrogen content per leaf area was associated with the enlargement of leaf area which may bring about an increased utilization of solar radiation under a properly balanced water supply.

This investigation was initiated in order to find out if differences could be detected between different varieties regarding their photosynthetic activity and other leaf characters with some old and modern commercially cultivated wheats of West Pakistan. In the case of a modern wheat cultivar which shall

be dealt with in this paper, the change from "thin, large" leaves towards "thick, small" leaves seems to be going on under abundant supply of nitrogen and properly balanced water supply resulting in an increased utilization of solar radiation, as in the case of modern rice varieties which has already been stated (TSUNODA, 1959).

Materials and Methods

The seeds of six commercially cultivated wheat varieties of West Pakistan shown in Table 1 and Fig. 1 were germinated in petri-dishes in incubator at about 20-25°C and after germination they were planted in plastic pots (9 cm diameter by 20 cm height) containing river silt in the glass-house in different three experiments on November 18th, 1967; December 1st, 1968; and May 7th, 1969; respectively. Two Seedlings were planted in each pot, one plant was left after thinning for the examination. Pots were randomized at planting and repositioned randomly at various times during the course of experiments. The plants were irrigated daily and large plants were watered twice a day if necessary. A nutrition solution (Ammonium sulphate 47 g, Sodium phosphate dibasic 25 g, and Potassium chloride 12 g in 1 litre of water) was applied at the rate of 10 ml per pot before planting and afterwards every 10-15 days interval.

The photosynthesis of full expanded individual leaves attached to the intact plants was observed in a transparent glass chamber under artificial light. The concentration of CO₂ in

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Table 1. Characteristics of the West Pakistani Commercial Wheat Varieties

S. No.	Variety	Year of approval	Parentage	General Characters
1.	C 228	1941	Hard Federation × 9 D	Plants tall, weak stemmed, ears bearded rather lax and smooth. Grains amber and of good quality. Susceptible to three rusts. It was recommended for late sowings.
2.	C 271	1957	C 230 × IP 165	Plants tall somewhat stiff stemmed. Ears beardless, mid lax, glumes pubescent, grains amber and bold. Resistant to stripe rust but highly susceptible to leaf and stem rusts. It was recommended for rich soils.
3.	C 273	1957	C 209 × C 591	Plants tall, ears bearded, mid dense, glumes white; grains amber and of good quality. Susceptible to three rusts. It was recommended for irrigated lands.
4.	C 518	1933	Type 9 × 8 A	Ears bearded, densely fitted. Awns greyish black. Susceptible to three rusts. Stem better than C 591. It was recommended for rich soils.
5.	C 591	1934	Type 9 × 8 B	Plants tall, bearded, Susceptible to three rusts, grains amber and attractive. It was recommended for irrigated lands.
6.	Mexi-Pak	1966	Penjamo × Gabo	Plants semi-dwarf, stiff stemmed and high tillering and yielding wheat variety. Ears bearded with higher number of florets. Grains amber and of medium quality. Resistant to stem and stripe rusts but moderately susceptible to leaf rust.

Fig. 1. Appearance of full grown specimens of the six commercial cultivated wheats of West Pakistan, used in all the experiments. The plants shown here have been cultured in glass-house. The varieties are from left: Mexi-Pak, C 271, C 273, C 518, C 591 and C 228.

the air entering and leaving the chamber was measured by means of Hitachi-Horiba EIA-1A infrared CO₂ gas analyzer in which the air temperature was kept at 20°C.

In order to study response to air flow rates, the leaves were exposed to 300 ppm CO₂ and temperature was maintained within a range of 20-23°C while air flow rates passing through the leaf chamber were changed from 0.5 to 2.0 litres per minute.

The methods of measuring and calculating the leaf photosynthetic rate, leaf area, leaf

dry weight and leaf nitrogen content were the same as described in a previous paper (KHAN and TSUNODA, 1970a).

For evaluating the transpiration rate, the dry-bulb and wet-bulb temperatures of the air entering and leaving the leaf chamber were measured with the aid of Iio MIC-165 high sensitivity thermometer. The moisture content at the entrance and the exit was calculated to evaluate the transpiration rate.

Results and Discussions

EXPERIMENT 1. Photosynthesis, leaf nitrogen and specific leaf weight and their interrelationships.

Photosynthetic rate per unit leaf area (P_A) estimated on the basis of 1.0 litre air flow rate and nitrogen content per leaf area are found to be positively correlated with a correlation coefficient value of $r = +0.574$ being significant at 1% level (Fig. 2). A further look into Fig. 2 and Table 2 indicated that a modern cultivated highest yielding wheat variety namely Mexi-Pak gave the highest photosynthetic rate per unit leaf area as well as nitrogen content per leaf area followed by a variety C 228. There existed significant differences between Mexi-Pak and the remaining old varieties with respect to the photosynthetic rate as well as nitrogen content per leaf area.

Table 2 and Fig. 3 very clearly revealed that variety Mexi-Pak followed by variety C 228 gave the highest specific leaf weight values and there existed significant differences between Mexi-Pak and the remaining four old varieties. Moreover, it is quite obvious from Fig. 3 that there is a strong positive correlation between photosynthetic rate per unit leaf

area and specific leaf weight (leaf dry weight per unit leaf area) with a correlation coefficient value of $r = +0.574$ which is statistically highly significant at 1% level. A higher P_A of variety Mexi-Pak seems to be associated with a higher specific leaf weight and a lower P_A of variety C 273 with a lower specific leaf weight. PEARCE *et al.* (1969) showed that there was a strong

Table 2. Means and least significant differences.

Varieties	Experiment 1 (March, 1968)				Experiment 3 (June, 1969)	
	Photosynthetic rate per unit leaf area ($\text{mgCO}_2 \text{ dm}^{-2} \text{ hr}^{-1}$)	Nitrogen content per leaf area (mg/dm^2)	Specific leaf weight (mg/cm^2)	Nitrogen percent content per leaf dry weight	Photosynthetic rate per unit leaf area ($\text{mgCO}_2 \text{ dm}^{-2} \text{ hr}^{-1}$)	Transpiration rate ($\text{mgH}_2\text{O cm}^{-2} \text{ hr}^{-1}$)
1. C 228	33.8	23.3	5.52	4.46	28.0	8.9
2. C 271	30.5	20.5	5.19	3.65	27.1	11.5
3. C 273	28.6	21.3	5.21	4.16	24.9	8.1
4. C 518	30.1	19.9	5.05	4.16	27.3	10.4
5. C 591	31.5	21.0	5.03	4.62	30.1	10.8
6. Mexi-Pak	36.0	25.3	6.16	4.97	34.0	12.6
LSD at 5%	4.3	1.6	0.74	0.54	7.9	1.9
LSD at 1%	5.8	2.2	1.00	0.73	11.3	2.7

Fig. 2. Relationship between nitrogen content and photosynthetic rate. (March, 1968)
** Significant at 1% level.

Fig. 3. Relationship between specific leaf weight and photosynthetic rate. (March, 1968).

positive correlation between photosynthetic rate per leaf area and the specific leaf weight among strains of alfalfa. The same correlation was observed by MURATA (1961) among rice varieties and by OJIMA and KAWASHIMA (1968) among soybean varieties at least on the leaves of the plants at early stages of growth. Similar type of correlations have been observed on strains of different species of *Triticum* and *Aegilops* (KHAN and TSUNODA, 1970 bc). The results from the present studies on West Pakistani wheat varieties lend a strong support to these findings.

The correlations observed between photosynthetic rate per unit leaf area and nitrogen content per leaf area (Fig. 2) almost resembles with that observed between photosynthetic rate per unit leaf area and specific leaf weight (Fig. 3).

Fig. 4 reveals a strong positive correlation between specific leaf weight and leaf areal nitrogen content with a correlation coefficient value of $r = +0.707$ statistically highly significant even at 1% level. Here again in case of variety Mexi-Pak, with the increase in nitrogen content per leaf area, an increase in the specific leaf weight is seen very clearly. These results coincide with the findings of KHAN and TSUNODA (1970bc).

The contents of Table 2 clearly indicated

Fig. 4. Relationship between nitrogen content and specific leaf weight. (March, 1968)

that variety Mexi-Pak showed also the highest percent of nitrogen content per leaf dry weight followed by variety C 591 and C 228. It can be further seen that there existed significant differences between Mexi-Pak and the remaining old wheat varieties at 5% level of least significant difference. In rice as well as in sweet potatoes, varieties adapted to heavy manuring tended to show a high percentage content of nitrogen in the leaf blade, as compared with those adapted to light manuring (TSUNODA, 1953; 1959; and 1960). BABA (1954) also pointed out that, in rice, that Japanese varieties fitted for heavy manuring showed, in general, a high percentage content of nitrogen as compared with varieties of *indica* types fitted for light manuring. The findings of this investigation agree with those of other workers mentioned above. From these results it may be suggested further that the percentage content of nitrogen in the leaf blade is worthy of attention to the varietal responsibility to fertilization.

KHAN and TSUNODA (1970a) described that wild plants tended to have "thick" small leaves showing high P_A values while cultivated wheats with "thin" large leaves showed low P_A values. Further, it was considered that this change from "thick" small leaves towards "thin" large leaves may have been proceeded in accordance with improved water supply. However, it should be mentioned that the cultivated types observed in the previous paper were mainly primitive cultivars. In the case of some modern wheat cultivars such as Mexi-Pak, the change of just reverse direction, i.e., from "thin" large leaves towards "thick" small leaves seems to be going on under abundant supply of nitrogen and other nutrients. It is worthy of mention here about the modern cultivated wheat variety of West Pakistan, Mexi-Pak, that it is adapted to heavy manuring and gives per acre yield as high as almost the double under heavy fertilization and properly irrigated conditions as compared with the old commercial wheat varieties of West Pakistan. Besides, when compared the depth of green colour of the leaves, Mexi-Pak variety showed very dark green colour as compared to other varieties which are having light green colours. It has been reported by

Fig. 5. Influence of air flow rate on photosynthetic rate in commercial wheat varieties of West Pakistan. (January, 1969)

Fig. 6. Influence of air flow rate on photosynthetic rate in commercial wheat varieties of West Pakistan. (March, 1969)

TSUNODA (1959) that the varieties adapted to light manuring tended to have "thin" horizontal and thinly dispersed leaves and it should not or need not be coloured so deep. Whereas, "thick" leaves, vertical leaves and densely gathered leaves, are the characteristics of the varieties adapted to heavy manuring and tend to be deeply coloured to absorb as much light as possible.

EXPERIMENT 2. Influence of different air flow rates on leaf photosynthesis.

The influence of different air flow rates on leaf photosynthesis in diploid, tetraploid and hexaploid species have been reported elsewhere (KHAN and TSUNODA, 1970c). It was pointed out that depending upon the leaf sizes, the highest photosynthesis was obtained at 1.0 litre air flow rate in case of diploid species which have smaller leaves or smaller single leaf area, while 1.5 litre gave the highest photosynthetic rates in case of tetraploids and hexaploid species having larger leaf sizes or larger single leaf area.

In the present investigation, the materials used are all cultivated common bread wheats, cultivars of hexaploid *Triticum vulgare* Vill. Here again the influence of different air flow rates on attached single leaves was studied in an attempt to know whether intraspecific differences could be detected between these materials. The results are presented in Figs. 5 and 6.

The data regarding the 1st observation, i.e., January, 1969 are presented in Fig. 5. It is quite obvious that all the varieties showed lower photosynthetic rates at lower air flow rates, i.e., 0.5 and 1.0 litres, whereas at 1.5 litre, all the varieties showed the highest photosynthetic values and at 2.0 litres it decreased again. At the optimum air flow rate, it is quite clear that variety Mexi-Pak followed by C228 and C271 varieties gave the highest photosynthetic rates. Varieties C591 and C518, which were released in the 1930's, showed the lowest photosynthetic values.

The data for the 2nd observation, i.e.,

March, 1969, are presented in Fig. 6. A through look into Fig. 6 indicates that at low air flow rates P_A values are low while the maximum P_A values are attained at 1.5 litres and again a tendency of decreasing P_A is observed here with the increase of air flow rate, i.e., at 2.0 litres. Here again Mexi-Pak variety followed by C 273 and C 228 showed the highest P_A values whereas C 591 and C 518, very old commercial varieties released in the 1930's gave the lowest P_A values.

While comparing the data of January with that of March, it is quite evident that with a few exceptions, almost results are the same in both the cases. However, in January's data, the P_A values are higher in general as compared with March observations. The reason may be either temperature or environmental differences or differences in single leaf areas. The second difference is that during March observations, there is a sharp increase in P_A values as compared with January's observations.

It coincides with the results already described in the previous paper that 1.5 litre air flow rate is the proper and adequate to get the highest photosynthetic rates in case of hexaploid varieties under our present system of measuring P_A .

EXPERIMENT 3. Leaf photosynthesis and leaf transpiration and their interrelationships.

The calculations for photosynthetic rates per unit leaf area and transpiration rates in this experiment were made on 1.5 litre air flow rate basing on the results of the preceding experiment that 1.5 litre air flow rate is proper and adequate to get the highest photosynthetic rates in case of hexaploid species. A very strong positive correlation was observed between photosynthetic rate per unit leaf area and transpiration rate (Fig. 7). A correlation coefficient value of $r=+0.728$ significant at 1% level was seen. A higher photosynthetic rate seems to be associated with a higher transpiration value and a lower photosynthetic rate with a lower transpiration rate.

Furthermore, it can be pointed out from Table 2 and Fig. 7 that variety Mexi-Pak exhibited highest photosynthetic rates per unit leaf area as well as transpiration rates among the materials under investigation. Variety C 273 gave the lowest photosynthetic rate and

Fig. 7. Relationship between transpiration and photosynthetic rate. (June, 1969)

transpiration values whereas the remaining varieties namely C 591, C 271, C 518 and C 228 gave the intermediate values in this respect. There existed significant differences between variety Mexi-Pak and C 273 for the photosynthetic rate as well as transpiration rate (Table 2). These findings resemble with that of already reported on strains of different species of *Triticum* and *Aegilops* (KHAN and TSUNODA, 1970 c) that photosynthetic rates per unit leaf area and transpiration rates are highly correlated positively.

Summary

Differences in photosynthetic rate per unit leaf area and transpiration rate of single attached leaves were observed among six commercially cultivated wheat varieties of West Pakistan. Mexi-Pak, a modern semi-dwarf variety that yields high under heavy fertilized and properly irrigated conditions showed higher photosynthetic rate and higher transpiration rate on leaf area basis than old Pakistani wheat varieties. High photosynthetic rate was associated with high transpiration rate, high specific leaf weight and high nitrogen content per leaf area. Percentage of leaf nitrogen content to leaf dry matter

was also high in Mexi-Pak as compared with old varieties.

In the previous papers it was pointed out that wild species of *Triticum* and *Aegilops* tended to have “thick” small leaves showing higher photosynthetic rates per leaf area while cultivated wheats with “thin” large leaves showed low photosynthetic rates. Further, it was considered that this change from “thick” small leaves towards “thin” large leaves may have been proceeded in accordance with improved water supply. In the case of some modern wheat cultivars such as Mexi-Pak, the change of just reverse direction, i.e., from “thin” large towards “thick” small leaves seems to be going on under abundant fertilizer supply.

The influence of different air flow rates passing through the leaf chamber was studied on the same materials. The results coincided with those reported in the previous paper that 1.5 litre per minute air flow rate is the proper and adequate to get the highest photosynthetic rates in case of hexaploid varieties under our present system of measuring photosynthetic values.

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西パキスタン栽培小麦 6 品種の葉光合成、葉蒸散率の差異

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西パキスタンの栽培小麦 6 品種について着生単葉の単位葉面積当りの光合成、蒸散率の差異を観察した。多肥で適当に灌漑される条件下で高い収量を上げる最新の半矮性品種、Mexi-Pak が旧来のパキスタン小麦品種に比べ葉面あたり高い光合成率、高い蒸散率を示した。高い光合成率は、高い蒸散率、高い葉面当り乾物量、高い葉面当り窒素量と相伴なっていた。葉乾物に対する葉窒素の含有比も Mexi-Pak の方が古い品種に比べ高かった。

前報で、小麦属、*Aegilops* 属の野生種は“厚い”小型葉を持ち葉面当り光合成率が高く、一方栽培小麦は“薄

い”大型葉を持ち葉面当り光合成率が低い傾向があること、更に、この“厚い”小型葉から“薄い”大型葉への変化は水分供給の改善にともなつて進行した可能性があることが指摘された。Mexi-Pak のような近代的な小麦栽培品種の場合には、ちょうど逆の“薄い”大型葉から“厚い”小型葉への変化が潤沢な肥料施用の下で進行している場合もあるように見うけられる。

同化箱の通気速度の影響を同じ材料について調査した。結果は前報と同じく、6 倍性品種の場合には毎分 1.5 l の通気速度が現装置において最高光合成率を得るのに適当十分なものであつた。