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The Role of 'Norin 10' Dwarfing Genes in Photosynthetic and Respiratory Activity of Wheat Leaves

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Summary. A comparative analysis of eight cultivars of spring wheat (*Triticum aestivum*) classified by height as tall (T), semi-dwarf (D_1), dwarf (D_2) and very dwarf (D_3) was conducted to study their efficiency of oxygen exchange during photosynthesis and dark respiration. Two cultivars were included in each height group.

Cultivars carrying 'Norin 10' dwarfing genes (D_1, D_2 and D_3) were found to have a significantly higher photosynthetic rate per unit leaf area than talls (T) that lack these genes. Among the 'Norin' gene carriers, dwarf group (D_2) was most efficient, followed by very dwarf (D_3) and semi-dwarf (D_1).

Photosynthetic rate and respiratory rate were found to have a positive relationship.

Key words: Wheat – 'Norin 10' dwarfing genes – Photosynthesis – Respiration

Introduction

It has now been amply demonstrated that dwarf or semi-dwarf cultivars of wheat carrying 'Norin 10' dwarfing genes, under favorable conditions of plant growth, have a better potential for grain production than the traditional talls, which they have recently replaced all over the world. How plants carrying these genes contribute to increased grain yield has been a subject of discussion. A number of studies in this connection have been made which emphasized the role of various yield components, including large number of tillers, grain number, high harvest index, etc. However, information on the physiological traits of these cultivars seems to be insufficient.

The present study was conducted with the view of gaining a better understanding of the role of 'Norin 10' dwarfing genes in such important physiological processes as photosynthesis and respiration.

Materials and Methods

Eight cultivars of Indian spring wheat (*Triticum aestivum*), classified for their height as tall (T, > 100 cm), semi-dwarf (D_1, 86-100 cm), dwarf (D_2, 71-85 cm) and very dwarf (D_3, < 71 cm), were cultured in pots filled with river clay-silt and fed with Hoagland nutritive solution at regular intervals. Two cultivars were included in each height group. Table 1 shows the names and parentages of the cultivars used. The cultivars classified as D_1, D_2 and D_3 involve one or more pairs of dwarfing genes derived from 'Norin 10', a Japanese cultivar. The pots, initially containing three seedlings but later thinned out to one each, were maintained in a greenhouse under natural light and temperature conditions. Flag leaf of same age from each cultivar was used as material for this study.

Photosynthetic oxygen evolution in light and respiratory oxygen absorption in dark were measured on the basis of leaf area using an oxygen electrode system (Rank Brothers Engineering, England). The procedure laid down by Ishii et al. (1977) was adopted.

Observations in four replications were recorded and statistically analysed following randomized block design. Newman-Keul's multiple range test was applied for comparison among various height groups. Simple correlations were also computed.

Results

Mean observations on oxygen exchange in photosynthesis and dark respiration processes along with height classification are presented in Table 2. It may be noted from the Table that 'Arjun' and 'Shera' (dwarfs, D_2) showed maximum amount of photosynthetic oxygen evolution followed by HD 2160 and 'Moti' (very dwarfs, D_3), 'Kalyansona' and 'Sonalika' (semi-dwarfs, D_1) and NP 852 and K 68 (talls, T). A similar trend may be seen for respiratory oxygen absorption, although there was overlapping in case of 'Moti' (D_3) and 'Kalyansona' (D_1).

The analysis of variance (Table 3) shows that there were significant differences among the cultivars for both characters. A further break-down of seven degrees of freedom of cultivars into within and between groups shows that highly significant differences in the photosynthetic

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Table 1. Names and parentages of the cultivars

Height group	Cultivar name	Parentage
T	NP 852	NP 761 X E 1915/NP 761
T	K 68	NP 773 X C 13
D_1	'Kalyanson'	[('Frontana' X 'Kenya 58-Newthatch') 'Norin 10-Brevor'] X 'Gabo 55'
D_1	'Sonalika	II 53-388-Andes' X 'Pitic "S" ' X 'Lerma Rojo 64' 'Pitic "S" ': 'Yaktana 54' X 'Norin 10-Brevor' 'Lerma Rojo': [('Yaqui 50' X 'Norin 10-Brevor') 'Lerma 52'] 'Lerma Rojo^2 '
D_2	'Arjun'	'Lerma Rojo 64A' X 'Sonora' 'Lerma Rojo 64A': [('Yaqui 50' X 'Norin 10-Brevor') 'Lerma 52'] 'Lerma Rojo^2 '
D_2	'Shera'	'Lerma Rojo 64A' X 'Snora 64'
D_3	HD 2160	'Masoc^3 ' X 'Yaktana 54' X 'Norin 10-Brevor' X 'Calidad-Tobari-Centrifin'/HD 1949 HD 1949: (P 61 IV-213 X 'Yaktana 54' X 'Norin 10-Brevor') X NP 852
D_3	'Moti'	(P 61 IV-213 X 'Yaktana 54' X 'Norin 10-Brevor') X NP 852

Table 2. Mean observations on oxygen exchange in photosynthesis and respiration

Height group	Cultivar	Oxygen exchange μmole/dm^2/hr	
		Photosynthesis	Respiration
T	NP 852	178.3	11.2
T	K 68	183.6	12.9
D_1	'Kalyansona'	216.2	21.3
D_1	'Sonalika'	211.7	17.2
D_2	'Arjun'	238.8	63.9
D_2	'Shera'	234.2	46.6
D_3	HD 2160	229.5	29.5
D_3	'Moti'	219.3	21.2

Table 3. Analysis of variance

Source	D.F.	Variance ratio	
		Photosynthesis	Respiration
Replication	3	1.47	0.73
Cultivar	7	27.80**	75.04**
– within T	1	0.52	0.31
– within D_1	1	0.57	1.89
– within D_2	1	0.61	33.60**
– within D_3	1	2.95	7.71*
– between groups	3	63.31**	160.58**
Error	21		

* Significant at 0.05
** Significant at 0.01

oxygen evolution and in the respiratory oxygen absorption rate did exist between the groups.

A comparative analysis of various groups is made in Table 4. It may be noted that the tall group of cultivars (T) showed a significantly lower oxygen exchange rate in photosynthesis and in respiration than all other groups (D_1, D_2 and D_3). Among D_1, D_2 and D_3, the dwarf group (D_2) showed the highest and the semi-dwarf (D_1) showed the lowest rate in photosynthesis and in respiration. The difference in the rates between D_2 and D_1 was statistically significant.

Figure 1 shows the relationship between the photosynthetic oxygen evolution and the respiratory oxygen absorption rate. The photosynthetic rate was positively related to the respiratory rate, and the simple correlation coefficient between the two rates among eight cultivars was 0.809, the correlation being statistically significant at 0.05 level.

Table 4. Comparison of different groups

Height group	Photosynthesis	Respiration
	Group means	
	Oxygen exchange	(μmole/dm^2/hr)
T	181.5	12.1
D_1	213.9	19.2
D_2	236.5	55.2
D_3	224.4	25.4
	Variance ratio	
T : D_1	7.73**	3.38*
T : D_2	13.11**	20.39**
T : D_3	10.22**	6.28**
D_1 : D_2	5.38**	17.00**
D_1 : D_3	2.48	2.89
D_2 : D_3	2.89	14.11*

*, ** Levels of significance as in Table 3

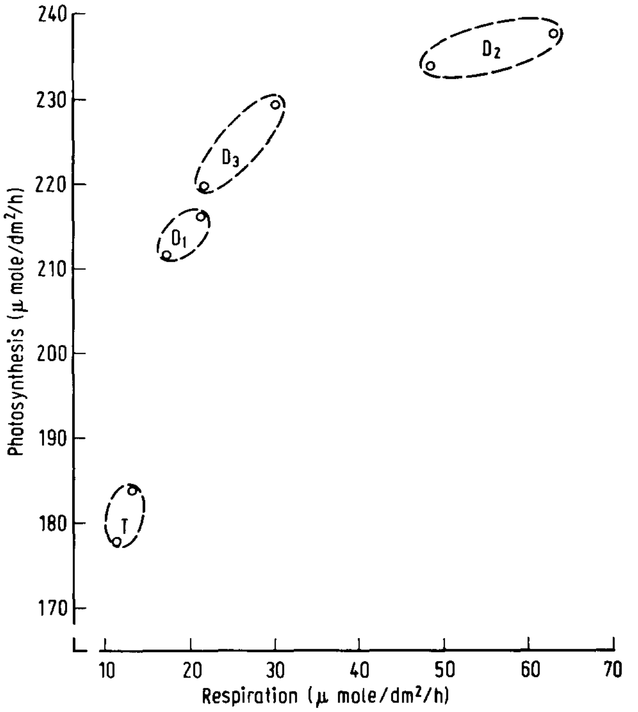

Fig. 1. Relationship between photosynthetic and respiratory oxygen exchange

Discussion

The present study clearly demonstrates that 'Norin 10' dwarfing genes play a significant role in increasing the photosynthetic rate per unit area of leaf. A higher photosynthetic activity in semi-dwarf wheats carrying 'Norin' genes has also been reported with Pakistani cultivars by Khan and Tsunoda (1970a), and with British cultivars by Lupton (1972) and Pearson et al. (1979), although in these reports the number of cultivars observed were limited.

A higher photosynthetic rate per unit leaf area does not necessarily bring about a larger dry matter production. Several studies have shown no relationship between grain productivity and exchange of photosynthetic oxygen (Bekina and Lysenko 1978) or carbon dioxide (Pearman et al. 1979). However, if a properly large leaf-area index can be achieved under favorable conditions for plant growth involving a sufficient supply of nutrients and water, high photosynthetic rate per unit leaf area may bring about a high dry matter production, as discussed previously by Khan and Tsunoda (1970a).

Moreover, Jain and Kulshrestha (1976) argued that 'Norin 10' dwarfing genes helped to partition the dry matter in the plant in a more favorable direction with respect to grain yield.

These two characteristics of the cultivars carrying 'Norin 10' dwarfing genes may make the plant more efficient from the point of view of grain production, provided that a properly large leaf-area index is guaranteed under favorable conditions of plant growth.

Khan and Tsunoda (1970a) pointed out that the high photosynthetic rate of a semi-dwarf wheat estimated by the carbon exchange of a whole attached leaf was associated with its high transpiration rate and with its high specific leaf weight as well as with high leaf nitrogen content per unit leaf area. These results suggest that the high photosynthetic activity of the semi-dwarf was related to the low gas diffusion resistance of the leaf on one hand and to a large amount of enzymes and other substances essential for carbon fixation on the other hand.

In the present study, the high photosynthetic rate of the cultivars carrying 'Norin 10' dwarfing genes was found to be linked with an increase in the respiratory rate. The photosynthetic rate, in this case, was estimated by the oxygen exchange of leaf slices placed in a buffer solution enriched with carbon dioxide, following the procedures of Ishii et al. (1977), which may eliminate the effect of stomatal gas diffusion resistance. It may be reasonable to infer that the 'Norin 10' dwarfing genes acted on the leaf structure in the direction of increasing the densitythickness of the leaf and the amount of various enzymes and other substances involved per unit leaf area which resulted in an increase in the photosynthetic rate as well as in the respiratory rate.

With barley, Kishitani et al. (1980) compared non-uzu and uzu isogenic lines and reported that uzu lines carrying a semi-dwarf gene *uzu* showed a higher photosynthetic rate per unit leaf area linked with a higher leaf nitrogen content per unit leaf area. In addition, there are a number of reports on the positive relationship between leaf nitrogen content, photosynthetic rate, and respiratory rate, e.g. Murata (1961) with rice and Khan and Tsunoda (1970b) with wheat.

In the present study, eight cultivars classified by their height as tall (T, $>$ 100 cm), semi-dwarf (D_1, 86-100 cm), dwarf (D_2, 71-85 cm) and very dwarf (D_3, $<$ 71 cm) were used, two cultivars being included in each height group. Among these four groups, D_1 showed a significantly higher rate than T and D_2 showed a significantly higher rate than D_1 in photosynthesis as well as in respiration. However, D_3 showed a rather lower rate of respiration when compared with D_2, and the difference in photosynthetic rate between D_3 and D_2 was not significant. These results seem to be informative as an example of the dose effect of 'Norin 10' dwarfing genes, because it is estimated that talls (T) do not have any 'Norin' dwarfing genes, semi-dwarfs (D_1) have one pair, and dwarfs (D_2) and very dwarfs (D_3) have two pairs of the genes. However, in order to get a more exact figure of the dose effect of 'Norin 10' dwarfing genes on photosynthesis and respiration, further investigations are needed using a larger number of cultivars with which the analysis of 'Norin 10' dwarfing genes has been completed.

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