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SHORT NOTE

A comparison of physiological and yield characters in old and new wheat varieties

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The Indian subcontinent has witnessed a spectacular improvement in yield of wheat during the past decade (Rao, 1978). This is reflected in the improvement of the average national yields as well as of those regions where wheat is grown as an irrigated crop (Sinha & Aggarwal, 1981). However, after the release of the double dwarf variety Kalyansona, only marginal improvement in yield has occurred in recent years. Despite this, the semi-dwarf character continues to be considered a major factor for improvement of wheat. Asana & Chattopadhyay (1970), Konar & Asana (1975), and Wattal & Asana (1976) observed no significant difference in yield between tall and semi-dwarf (medium tall) varieties in pot culture experiments where lodging was prevented and competition was partly reduced. They ascribed prevention from lodging and improvement in the ratio of grain to total above-ground dry matter as major advantages in the modern varieties. Somewhat similar conclusions have recently been drawn by Austin *et al.* (1980). However, a detailed comparison of various physiological and biochemical characters has not been made to determine whether any advance has occurred in basic processes such as photosynthesis and nitrogen assimilation. The present study was an effort in this direction.

MATERIALS AND METHODS

Thirty cultivars released in different decades of the present century were used (Table 1). All the cultivars released up to 1960 were tall and those released after that (except for K 65 and K 68) were dwarfs. Three replicates of eight rows, each 2 m long, were grown in a split-plot design with 0 and 100 kg/ha of nitrogen as main plots. Rows were 20 cm apart and the distance between plants in a row was 2 cm. Phosphorus and potassium at the rate of 60 and 40 kg/ha respectively were also added. The fertilizers were given before seeding as a single dose. All plots were kept irrigated. Fungicides were sprayed to prevent stem rust infection, which is the only prevalent disease in the region. The experiment was sown on 1 December and there was no lodging in any of the cultivars.

Yield and yield components. Before harvest the shoots and ears in an area of 1 m^2 on each plot were counted. Later the above-ground dry matter was harvested and weighed. Ears were threshed to obtain grain yield/m^2. Simultaneously ears from five main shoots of each replicate were harvested for their ear weight, number of spikelets and grains, and grain weight.

Physiological and biochemical analysis. Two fully expanded upper leaves from 60-day-old plants were used for the entire analysis. Leaves were taken from all the three replicates. None of the varieties had reached ear emergence at this time.

Components of nitrogen assimilation. Nitrate reductase (NR) activity was determined *in vivo* by the method of Klepper, Flesher & Hageman (1971). Amino acids, soluble proteins and total nitrogen were analysed following Rosen (1957), Lowry *et al.* (1951) and Novozamsky *et al.* (1974) respectively.

Photosynthesis components. Stomatal resistance was determined on the upper and lower surface of leaves with a diffusion resistance porometer (L1·65, Lambda Instrument Corporation, USA) following Kanemasu, Thurtwell & Tanner (1969). Leaf area was determined for the main shoot with an automatic area meter (AAM-7, Hayashi Denkoh Co., Japan). Chlorophyll content and RuBP carboxylase activity was analysed following Arnon (1949) and Neales, Treharne & Wareing (1971). The rate of photosynthesis was determined by using $^{14}CO_2$ following the method of Shantakumari & Sinha (1972).

All results except for dry matter and yield are given as means of tall and dwarf cultivars.

Table 1. *List of cultivars used*

Decade	Cultivar
1901–10	NP 4
1911–20	Pb 11, NP 52
1931–40	C 591
1941–50	Niphad 4, NP 710, NP 718
1951–60	NP 761, NP 809, NP 824, NP 839, NP 846, NP 852, NP 875, NP 880, NP 883, C 281, C 306
1961–70	Lerma Rojo, Sharbati Sonora, Sonora-64, Kalyansona, K 65, K 68
1971–80	Moti, HD 2143, HD 2009, WL 711, HD 2204

Table 2. *Effect of nitrogen application on biomass and yield of tall wheat cultivars*

	Biomass (g/m²)		Yield of grain (g/m²)	
Treatment... Cultivar	N_0	N_{100}	N_0	N_{100}
NP 4	904	1641	320	446
NP 52	921	1453	278	424
NP 165	854	1591	303	410
NP 710	871	1591	313	430
NP 718	787	1457	283	455
NP 761	686	1374	202	467
NP 809	837	1624	212	340
NP 824	1021	1591	383	425
NP 839	1021	1557	257	506
NP 846	865	1239	255	331
NP 852	720	1591	237	486
NP 875	954	1474	300	484
NP 880	988	1437	283	502
NP 883	1038	1658	335	484
C 281	887	1256	256	331
C 306	1021	1407	402	556
C 591	937	1675	327	428
K 65	737	1373	266	412
K 68	937	1507	375	459
Niphad 4	670	1423	156	313
Pb 11	804	1373	238	311
Mean	879	1490	278	429
S.E.	65	94	36	28

Table 3. *Effect of nitrogen application on biomass and yield of dwarf wheat cultivars*

	Biomass (g/m²)		Yield of grain (g/m²)	
Treatment... Cultivar	N_0	N_{100}	N_0	N_{100}
Lerma Rojo	803	1289	296	395
Sharbati Sonora	485	1071	196	418
Sonora-64	670	988	280	367
Moti	748	1323	249	544
Kalyansona	619	1206	307	543
HD 2009	734	1478	306	420
HD 2143	720	1574	260	423
WL 711	1289	1725	556	634
HD 2204	736	1445	318	505
Mean	756	1345	308	472
S.E.	94	75	43	31

RESULTS

All the tall varieties were more than 100 cm in height; the semi-dwarf were between 70 and 85 cm whereas the dwarfs were less than 70 cm in height. All the old varieties belonged to the first category.

In tall varieties biomass ranged from 670 to 1038 g/m² with an average of 879 g/m² at the N_0 level of nitrogen (Table 2). All varieties responded to nitrogen application in biomass production which ranged from 1239 to 1675 g/m² with an average of 1490 g/m². Tall varieties did not differ significantly in biomass at the N_{100} level of nitrogen. Semi-dwarf and dwarf varieties produced an average biomass of 756 g/m² at N_0 and 1345 g/m² at N_{100} (Table 3). If we exclude WL 711 which was unusual, the average biomass would be 689 and 1296 g/m² at N_0 and N_{100} respectively. Therefore, it is clear that older varieties produced more biomass than the modern varieties at both the levels of nitrogen.

The average grain yield of tall varieties was 278 and 429 g/m² at N_0 and N_{100} respectively, clearly indicating that tall varieties also responded to nitrogen if they were prevented from lodging. The average grain yield of semi-dwarf and dwarf varieties was 308 and 472 g/m² at N_0 and N_{100} levels respectively. However, an important point to note was that among the tall types only three out of 21 gave yields more than 500 g/m² but among semi-dwarf and dwarfs, four out of nine did so.

Dwarf varieties produced more tillers and ears than tall types at the N_0 level, but the number became the same at the higher nitrogen level (Table 4). Number of grains per ear was 56 in dwarf varieties and 49 in tall cultivars. At both levels of nitrogen, dwarf cultivars maintained a higher ratio of grain to total above-ground D.M. (harvest index) than talls.

Among the characteristics associated with photosynthesis, the rate of photosynthesis, RuBP carboxylase activity, chlorophyll content and stomatal conductance showed only a slight difference between old and new varieties (Table 4). Both old and new varieties responded to nitrogen application, although the response by new varieties usually was higher than the older varieties par-

Table 4. *Response of tall and dwarf wheat cultivars to nitrogen application*

	Old (tall)		New (dwarf)	
	N_0	N_{100}	N_0	N_{100}
Photosynthesis (leaf laminae)				
Photosynthesis rate*	22·8 ± 2·56	28·9 ± 3·60	28·8 ± 3·23	39·2 ± 4·20
RuDP carboxylase†	534 ± 40·0	665 ± 50·0	458 ± 60·0	595 ± 40·0
Chlorophyll content‡	6·80 ± 0·23	10·13 ± 0·39	7·36 ± 0·32	11·52 ± 0·58
Stomatal resistance,§ upper	6·29 ± 0·31	5·99 ± 0·26	5·91 ± 0·24	5·06 ± 0·27
lower	7·90 ± 0·28	6·96 ± 0·29	7·45 ± 0·30	6·20 ± 0·22
Leaf area‖	54·8 ± 6·11	78·7 ± 6·40	47·1 ± 4·20	73·48 ± 0·46
Nitrogen (leaf laminae)				
Nitrate reductase¶	6·10 ± 0·26	14.75 ± 0·37	5·90 ± 0·23	15·95 ± 0·44
Amino acids‡	16·4 ± 1·1	27·4 ± 1·6	14·8 ± 0·98	25·1 ± 1·47
Soluble protein‡	177 ± 4·2	158 ± 7·4	142 ± 8·5	156 ± 13·0
Total nitrogen‡	7·96 ± 0·45	10·34 ± 0·49	14·24 ± 1·00	17.07 ± 0.68
Yield components				
No. of tillers/m²	253 ± 33·0	465 ± 69·0	312 ± 40·0	459 ± 45·0
No. of ears/m²	232 ± 36·0	404 ± 60·0	289 ± 55·0	410 ± 35·0
Biomass (g/m²)	879 ± 65·0	1490 ± 94·0	756 ± 94·0	1345 ± 75·0
Yield (g/m²)	278 ± 36·0	429 ± 28·0	308 ± 43·0	472 ± 31·0
Harvest index	32	29	41	35
No. of spikelets/ear	19 ± 0·6	19 ± 0·4	19 ± 0·5	20 ± 0·4
No. of grains/ear	49 ± 2·6	45 ± 1·6	56 ± 3·0	54 ± 1·6
Grain wt./ear (g)	1·99 ± 0·10	1·88 ± 0·08	2·19 ± 0·10	1·95 ± 0·12
Ear wt./ear (g)	2·89 ± 0·13	2·59 ± 0·13	3·07 ± 0·16	2·63 ± 0·15
1000-grain wt. (g)	37·3 ± 0·53	37·4 ± 0·12	35·2 ± 0·40	33·8 ± 0·16

* Mg CO_2/h/dm²; † μmol CO_2/h/gdw; ‡ mg/gdw; § sec/cm²; ‖ cm²/shoot; ¶ μmol NO_2^-/h/gdw.

ticularly in respect of the rate of photosynthesis (Table 4).

Nitrogen assimilation assessed in terms of nitrate reductase activity, free amino acids in leaves, soluble protein and total protein contents also showed no significant difference among the old and new varieties (Table 4). Indeed, new varieties responded more favourably to nitrogen application in all characters except the total protein content of leaves. However, the total protein nitrogen of leaves in new varieties was higher than old varieties at both levels of nitrogen.

DISCUSSION

In our studies we have made no effort to determine the contribution of a variety in improvement of wheat yields over the past decades as attempted by Silvey (1979) and Austin *et al.* (1980). Nonetheless, it is clear that, on average, modern varieties have higher yield potential under field conditions. In our experiments, we did not achieve yields of more than 6·0 t/ha in dwarf varieties with the exception of WL 711, because such yields require more than 100 kg N/ha. Furthermore, it appears that among tall varieties no significant improvement occurred from 1910 till the mid-sixties. A simple reason for this could be that in India a major objective in wheat breeding was disease resistance (Pal, 1966). Secondly, the recommended highest level of nitrogen was 40 kg/ha, primarily because of lack of availability of inorganic fertilizers as well as lodging. Therefore, the old varieties were selected for low-input agronomy.

It is apparent from our studies that dwarf types, although producing less dry matter, have higher grain yield than talls because of higher partitioning in favour of grains. Dry-matter production is dependent upon net assimilation rate which is dependent upon leaf area and net photosynthesis rate at a given time. Net photosynthesis is influenced by stomatal resistance, mesophyll resistance represented by the carboxylating system, respiration and photorespiration (Leopold & Kriedemann, 1964). The higher rates of photosynthesis in dwarf types at the high level of nitrogen may, therefore, be accounted for by increased activity of RuBP carboxylase, chlorophyll content and stomatal conductance (Table 4). Our results also bring out indirectly the importance of respiration studies, because despite higher rates of net photosynthesis as well as increased leaf area, the dwarf types did not produce more dry weight.

There was a very significant increase in total nitrogen content in the leaves of dwarfs at both nitrogen levels. Since amino nitrogen as well as soluble protein content showed no obvious difference, it is likely that more nitrogen was present in structural components of dwarf types.

In conclusion, it appears that at low levels of nitrogen there is no significant difference between old and new varieties in respect of photosynthesis and nitrogen assimilation. However, dwarf cultivars respond more when nitrogen availability is higher. Secondly, improvement in biomass production while retaining the harvest index of modern varieties may lead to further yield improvement.

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