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PHYSIOLOGICAL ANALYSIS OF GROWTH AND PRODUCTIVITY IN WHEAT CULTIVARS

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SUMMARY

Fifteen promising wheat cultivars developed between sixties and nineties in India were evaluated for their morpho-physiological traits associated with growth and productivity. Among the cultivars of different stature and duration, semi-dwarf long duration cultivars, viz. Kalyansona, HD 2643, HD 2687, UP 2338 and PBW 343 recorded highest productivity followed by semi-dwarf short and medium duration cultivars namely Arjun, Moti, HD 2285, HD 2329, Pratap and Kundan, while tall and semi-tall cultivars (C 306, K 68 and Sonalika) manifested lowest grain yield. The maximum productivity in semi-dwarf long duration cultivars was attributed to marked increase in their biological yield, leaf area index, grains/ spike, days to flowering and grain growth rate. The enhancement in productivity of semi-dwarf short and medium duration cultivars over tall and semi-tall cultivars was mainly attributed to marked improvement in their harvest index. However, lowest grain yield in tall and semi-tall cultivars was probably due to their poor leaf area index and harvest index. The net photosynthetic rate of flag leaf at flowering and post flowering stages and chlorophyll content did not show any relationship with grain yield in tested wheat cultivars. Thus, further improvement in biological yield without reduction in present level of harvest index (45-46%) either through greater leaf area duration or increased leaf photosynthetic activity may possibly result in further improvement of wheat productivity.

***Key words*: Biological yield, harvest index, leaf area index**

INTRODUCTION

The landmark increase in the productivity of wheat in India and elsewhere in the world have been achieved mainly due to the development of semi-dwarf lodging resistant high yielding cultivars and better crop management technologies (Chandler 1972, Jain 1986, Swaminathan 1996). The production efficiency of semi-dwarf wheat genotypes enhanced markedly under better crop nourishment mainly due to marked increase in their harvest index without significant improvement in biomass production (Kulshrestha and Jain 1982, Jain 1986, Singh and Upadhyay 1986, Reynold *et al*. 1999). Since, HI is approaching a ceiling value, further increase in yield has to come through increase in crop biomass (Sharma-Natu and Ghildiyal 2005). Significant reduction in plant stature led to greater conversion of vegetative biomass into reproductive sink (grains) in one hand, and tolerance to lodging under better inputs on the other hand (Kertesz 1984, Jain 1986, Reynold *et al*. 1999). The higher productivity of semi-dwarf wheat cultivars has been attributed to their greater leaf photosynthetic rate, stomatal conductance and canopy temperature depression (Fischer *et al*. 1998). Though a lot of work has been done on physiological analysis of growth and productivity in wheat (Asana 1968, Fischer *et al*. 1998, Reynold *et al*.

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1999), the information on physiological characteristics of newly developed high yielding wheat cultivars namely HD 2687, UP 2338 and PBW 343 is inadequate. Keeping this in view a field experiment was undertaken with fifteen promising wheat cultivars comprising traditional tall, improved semi-tall, semi-dwarf and dwarf cultivars developed during last four decades to know the morpho-physiological characters associated with growth and productivity for further development of promising wheat cultivars.

MATERIALS AND METHODS

Fifteen promising wheat cultivars developed in India (Table 1) were evaluated in the field at the research farm of Indian Agricultural Research Institute, New Delhi during two consecutive growing seasons, 1999-2000 and 2000-2001. The experiment was conducted in a randomized block design (RBD) with three replicates. Seeds were sown using dibbler at 20 x 10 cm distance @ 3 seeds/hole to obtain uniformity in the number of hills and plants per unit land area. Normal agronomic practices such as weeding, irrigation and fertilization with recommended dose (120:60:40Kg N:P:K /ha) were followed during the crop-growing season for proper crop growth and development. Plant sampling was done at anthesis to record LAI and at physiological maturity for growth and yield parameters. Chlorophyll content and leaf area index were determined following Yoshida *et al*. (1976). Net photosynthetic rate of flag leaf was measured using photosynthesis system (LI COR 6200, USA) at anthesis and 15 days after anthesis in three replicates. The term biological yield mentioned here in the text and tables refers to the above ground total dry weight (shoot dry weight) /unit land area (Donald and Hamblin 1976). Plants of tall cultivars, C 306 and K 68 were prevented from lodging by supporting them with the help of stick so as to find their actual grain and biological yields.

RESULTS AND DISCUSSION

The wheat cultivars of diverse stature (tall, semi-tall, semi-dwarf and dwarf) and growth duration (short, medium and long) showed marked difference in their growth and morpho-physiological characters, which finally resulted in remarkable difference in their grain yield and yield components. Although the mean grain yield of dwarf and semi-dwarf group of cultivars was significantly higher than those of tall and semi-tall group of cultivars, but there was no significant difference in grain yield between short, medium and long duration cultivars within semi-dwarf group (Table 1). Wheat cultivars showed greater coefficient of variation (CV) in grain yield (12.5%) compared to biological yield (8.8%) and harvest index (9.1%). Varietal variation in various growth and yield parameters of wheat have been reported by several investigators (Asana 1968, Jain 1986, Fischer *et al.* 1998, Reynold *et al*. 1999). Among the cultivars evaluated, tall and semi-tall cvs. namely C 306, K 68 and Sonalika registered lowest grain yield (4.2-4.3 t ha^{-1}), which was mainly due to poor harvest index (36-37 %) in traditional tall cvs. C 306 and K 68, and both poor harvest index (40%) and low biological yield (10.5 t ha^{-1}) in semi-tall cv. Sonalika. The poor harvest index in these cultivars might be primarily due to their tall stature and secondly because of their susceptibility to lodging. The lowest biological yield in semi-tall cv. Sonalika (10.5 t ha^{-1}) may perhaps be due to its lesser days to flowering and maturity duration. The short and medium duration dwarf and semi-dwarf cultivars (Moti, Arjun, Pratap, HD 2285, HD 2329 and Kundan) manifested relatively higher grain yield (5.0-5.8 t ha^{-1}) than tall and semi-tall cultivars (4.2-4.3 t ha^{-1}) mainly because of marked improvement in their harvest index (42-52 %), as the biological yield of these cultivars (10.5-12.4 t ha^{-1}) was not significantly higher than those of tall and semi-tall cultivars (Table 1). However, the late flowering cultivars, viz. Kalyansona, HD 2643, HD 2687, UP 2338 and PBW 343 recorded highest grain yield (6.0-6.2 t ha^{-1}) mainly due to their greater biological yield (13.0-13.5 t ha^{-1}) owing to longer days to flowering (100 days) and maturity (140 days), greater leaf area index (4.7-5.3), grains/spike (48-80 nos.) and harvest index (44-47%).

Aksel and Johnson (1961) also reported greater yield in late flowering cultivars of cereals. Although the late flowering wheat cultivars had shorter grain filling duration, but it did not hamper their grain productivity possibly due to its compensation by higher grain growth in these cultivars. Nass and Reiser (1975) reported that the length of grain filling period was not an important factor in

Table 1. Varietal variation in growth characters (at anthesis) and yield components in wheat (pooled mean of 1999-2000 and 2000-2001 seasons)

Variety	Plant Stature	Growth duration	Plant height (cm)	Leaf area index	Days to anthesis (days)	Anthesis to maturity	Days to maturity (days)	Total chl. (mg g^{-1} leaf wt.)	Photosynthetic rate (µmol m^{-2} s^{-1})		No. of spikes m^{-2}	Grain growth rate (mg g^{-1} d^{-1})	No. of grains $spike^{-1}$	1000 grain wt. (g)	Grain yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
									Anthesis	15 DAA							
C 306	Tall	Medium	112	3.6	85	45	130	1.57	19.71	14.76	250	1.00	40	44	4.2	11.4	37
K 68	Tall	Medium	118	3.5	90	45	135	1.85	25.87	15.74	280	0.85	44	37	4.3	12.0	36
Sonalika	Semi-tall	Short	96	3.2	80	45	125	1.96	21.01	15.20	340	1.03	35	37	4.2	10.5	40
DT 46	Semi-tall	Medium	100	5.0	85	50	135	1.91	22.00	11.45	250	0.80	51	39	5.4	13.5	40
Pratap	Semi-dwarf	Medium	93	5.0	95	45	135	1.57	20.34	14.30	300	0.93	45	40	5.4	12.4	44
HD 2285	Semi-dwarf	Short	92	4.2	85	45	130	1.83	18.50	11.70	365	0.76	46	33	5.2	12.4	42
HD 2329	Semi-dwarf	Medium	83	4.1	90	45	135	1.57	20.42	15.60	385	1.08	45	32	5.3	12.0	44
Kundan	Semi-dwarf	Medium	95	5.0	90	45	135	1.98	20.85	11.15	245	1.10	47	52	5.8	12.3	45
K.Sona	Semi-dwarf	Long	88	5.3	100	40	140	1.65	14.56	11.90	280	1.30	80	28	6.2	13.2	47
HD 2643	Semi-dwarf	Long	87	4.8	100	40	140	1.69	20.04	13.68	285	1.35	48	45	6.1	13.5	45
HD 2687	Semi-dwarf	Long	83	5.2	100	40	140	1.98	16.13	11.10	300	1.20	65	32	6.0	13.3	45
UP 2338	Semi-dwarf	Long	85	4.7	100	40	140	1.87	15.30	11.40	300	1.14	55	34	6.0	13.6	44
PBW 343	Semi-dwarf	Long	84	5.0	100	40	140	1.59	23.87	13.88	330	1.20	48	40	6.1	13.2	46
Moti	Dwarf	Short	63	4.0	85	45	130	2.14	18.67	11.70	380	1.00	45	30	5.0	10.5	48
Arjun	Dwarf	Short	74	4.5	80	45	125	2.18	16.34	12.65	340	0.85	45	38	5.7	11.0	52
		LSD at 5%	20	1.5	5	5	8	0.28	4.50	3.50	65	0.35	12	8	1.2	1.8	8

LSD at 5%

determining yield in wheat. The grain yield improvement in Kundan may perhaps be due to late flowering (95 days) and delayed leaf senescence during grain filling, in Arjun, it might be due to highest harvest index (52 %). The highest number of spikes m^{-2} (365-385 nos.) might have contributed to yield improvement in dwarf cv. Moti and semidwarf cvs. HD 2285 and HD2329.

Plant height showed negative correlation with harvest index in wheat in the present study (Fig. 1 and Table 2). Such inverse relationship between stature and harvest index in wheat has also been reported by several investigators (Fischer and Kertesz 1976, Kerterz 1984, Reynold *et al*. 1999). Leaf area index showed a significant positive correlation with grain yield and biological yield (Table 2, Fig. 1).

The wheat cultivars showed variation both in net photosynthetic rate of leaf at flowering and post flowering (15 DAA) stages and leaf chlorophyll content. The highest net photosynthesis was observed in traditional tall cv K 68 and chlorophyll content in dwarf cultivars Moti and Arjun, but these characters did not show positive correlation with grain yield under present study. Photosynthesis measurement of a few minutes duration using defined leaf position at radiation saturation may not be assumed to represent the productive potential of the crop (Ghildiyal and Sirohi 1986, Sharma-Natu and Ghildiyal 2005). Indeed, an analysis of wheat bred at CIMMYT, Mexico revealed that stomatal conductance canopy temperature depression, maximum photosynthesis rate were all associated with yield progress (Fisher *et al.* 1998).

It is evident from the findings that marked increase in grain yield of wheat cultivars developed in India between 1960 to 1985 was mainly due to significant improvement in their harvest index (36-37% in tall cultivars to 42-52% in semi-dwarf cvs.) without remarkable change in biological yield. However, further improvement in wheat productivity has probably been achieved mainly due to substantial improvement in the biological yield without major changes in harvest index with the evolution of longer duration superior cultivars (PBW 343, UP 2338, HD 2687) in mid nineties. These cultivars by virtue of taking more days to flowering and greater leaf area index, probably manifested greater leaf area duration and finally greater biological yield with higher sink potential (grains/spike) and biomass partitioning (harvest index). The study seems to indicate that these cultivars have raised the productivity of semi-dwarf wheat cultivars further through enhancing their biological yield as postulated by the wheat breeders and physiologists (Jain 1986, Reynold *et al*. 1999, Sharma-Natu and Ghildiyal 2005).

Table 2. Correlation coefficient between different growth and yield characters in wheat

Character	Plant height	LAI	Pn	Spikes/ m^2	Grains/ spike	1000 gn.wt.	G.Y./ m^2	B.Y./ m^2	H.I.	D.F.
Pl. height	1.0	-0.39	0.53*	-0.59	-0.24	0.39	-0.56*	0.09	-0.9**	0.09
LAI		1.0	-0.42	-0.31	0.7**	0.05	0.9**	0.7**	0.53*	0.41
Pn.			1.0	-0.8**	-0.62*	0.43	-0.41	-0.03	-0.56*	0.02
Spikes/m^2				1.0	-0.24	-.58*	-0.06	-0.44	0.38	-0.26
Grn./spike					1.0	-0.45	0.64*	0.58*	0.34	0.49
1000 g w						1.0	0.02	0.10	-0.19	0.01
G.Y./m^2							1.0	0.68*	0.71*	0.42
B.Y./m^2								1.0	-0.01	0.53*
H.I.									1.0	0.02
D.F.										1.0

Pn: Net photosynthetic rate; D.F: Days to anthesis; G.Y.: Grain yield; B.Y.: Biological yield; H.I.: Harvest index.

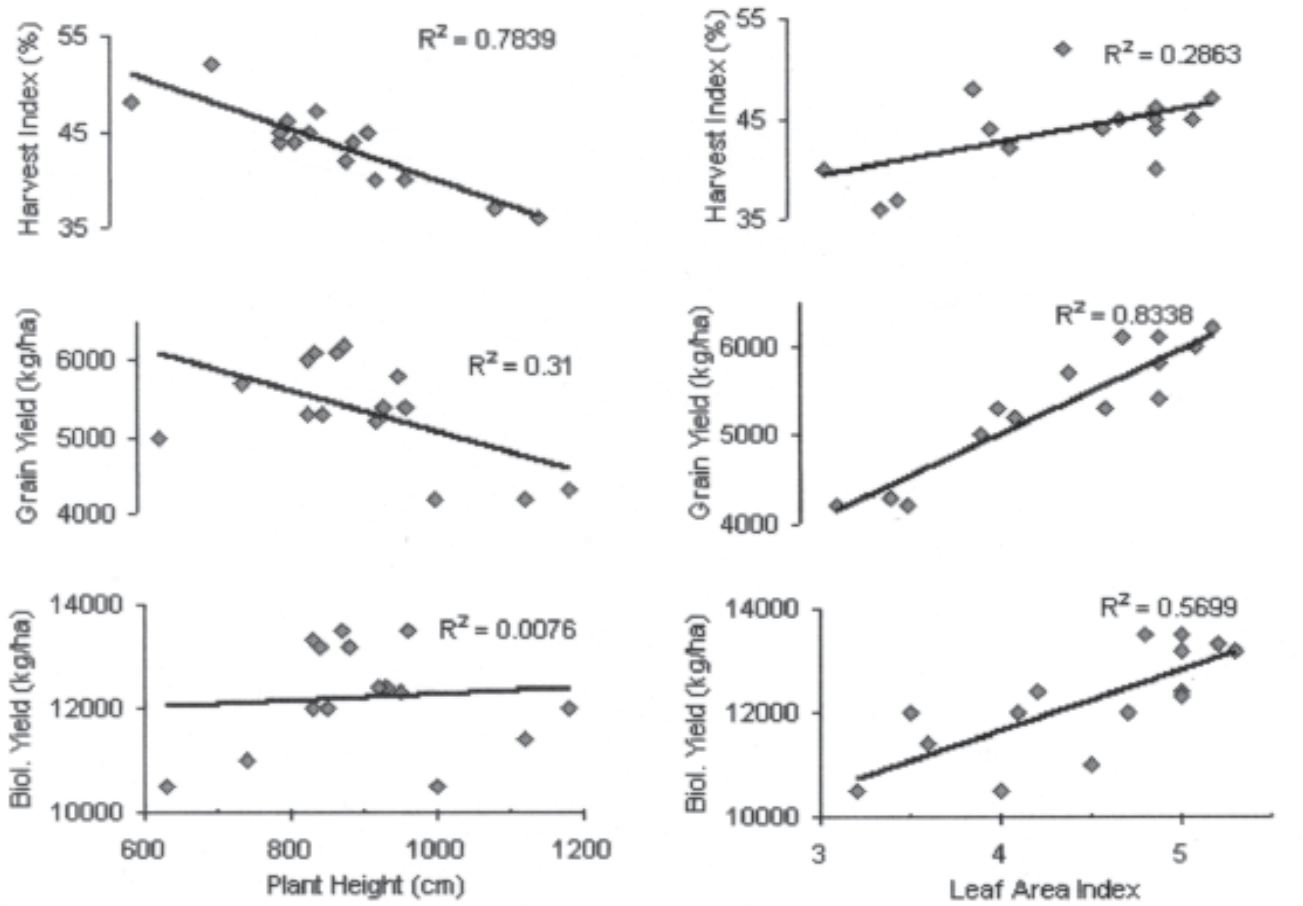

Fig. 1. Relationship between different characters of wheat cultivars

REFERENCES

Aksel, R. and Johnson, L.P.V. (1961). Genetic studies on sowing to heading period in barley and their relation to yield and yield components. *Can. J. Gen. Cytol*. **3:** 242-259.

Asana, R.D. (1968). In quest of yield. *Indian J. Plant Physiol* **11:** 1-10.

Chandler, R.F. (Jr.). (1972). The impact of improved tropical plant type on rice yield in south and southeast Asia. In: Rice Breeding, pp. 75-85. IRRI, Los Banos, Philippines.

Donald, C.M. and Hamblin, J. (1976). The biological yield and harvest index of cereals as agronomic and plant breeding criteria. *Adv. Agron.* **28:** 361-405.

Fischer, R.A. and Kertesz, Z. (1976). Harvest index in spaced population and grain weight in microplots as indicators of yielding ability in spring wheat. *Crop Sci*. **16:** 55-59.

Fischer, R.A., Rees, D., Sayre, K.D., Lu, Z.M., Condon, A.G. and Saavendra, A. (1998). Wheat yield progress associated with higher stomatal conductance and photosynthetic rate and cooler canopies. *Crop Sci.* **38:** 1468-1475.

Ghildiyal, M.C. and Sirohi, G.S. (1986). Photosynthesis and sink efficiency of different species of wheat. *Photosynthetica* **20:** 101-106.

Jain, H.K. (1986). Eighty years of post-Mendelian breeding for crop yield: Nature of selection pressure and future potential. *Indian J. Gen.* **46** (suupl.)**:** 30-53.

Kertesz, Z. (1984). Improvement of harvest index. In: Proc. 10th Congress of the EUCARPIA,19-24 June,1983, pp. 93-104. Wageningen.

Kulshrestha, V.P. and Jain, H.K. (1982). Eithty years of wheat breeding in India: Past selection pressure and future prospects. *Z. Pflanzenzuchtg* **89:** 19-30.

Nass, H.G. and Reiser, B. (1975). Grain filling period and grain yield relationship in spring wheat. Can. *J. Plant Sci*. **55**: 673 - 678.

Reynold, M.P., S. Rajaram, and Sayre, K.D. (1999). Physiological and genetic changes of irrigated wheat in the post green revolution period and approaches for meeting projected global demand. *Crop Sci*. **39:** 1611-1621.

Sharma-Natu, P. and Ghildiyal, M.C. (2005). Potential targets for improving photosynthesis and crop yield. *Curr. Sci.* **88:** 1918-1928.

Singh, M. and Upadhyay, M.K. (1986). Wheat improvement in *India. Indian J. Gen*. **46** (suppl.)**:** 187-197.

Swaminathan, M.S. (1996). Sustainable Agriculture: Towards an Ever Green Revolution. Konark Publication Pvt. Ltd., Delhi.

Yoshida, S., Forno, D.A., Cock, J.H. and Gomez, K.A. (1976). Laboratory Manual for Physiological Studies of Rice. Int. Rice Res. Inst., Laguna, Philippines.