EARLY MATURING COTTON GENOTYPES FOR ENHANCING THE PRODUCTIVITY OF COTTON - WHEAT SYSTEM: A PHYSIOLOGICAL ANALYSIS

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SUMMARY

Physiological analysis of cotton-wheat system with 20 cotton and 6 wheat genotypes was done in relation to the cropping system productivity. The duration of different cotton genotypes showed large variation and ranged from as early as 130 days to late up to 185 days. Genotypic variations in cotton genotypes for different morphological (shoot length, number of monopods and sympods), physiological (LAI and biomass) and yield (boll number and boll weight) parameters were significant. Higher vegetative growth (i.e. LAI) at 90 DAS and biomass (175-273 g plant $^{-1}$) at 120 DAS was observed mostly in early genotypes as compared to late genotypes. Many early maturing genotypes also possessed significantly higher number of sympodial branches (33-37 plant^{-1}) and significantly higher seed cotton yield (1.93 to 2.34 t ha^{-1}) than the late types (1.81 to 2.04 t ha^{-1}). Variety CNH-36, CNH-120, RS 810, Pusa 8-6, RS-2013, Vikas, LH-1556, Surbhi and hybrids Ankur 651, Omshanker and LHH-144 appeared physiologically more efficient in terms of photosynthesis (Pn) and photosynthetic water use efficiency (PWUE). In wheat, LAI at 120 DAS and biomass at maturity were significantly reduced in late sown wheat. The grain yield of six wheat genotypes after cotton ranged from 4.7 to 5.2 t ha^{-1} and was significantly higher in wheat genotypes UP 2338, HD 2687 and PBW 343. Late sowing of wheat due to late harvesting of cotton significantly reduced the wheat yield in all the genotypes. Photosynthesis, transpiration and photosynthetic radiation use efficiency were higher in timely sown wheat genotypes, however photosynthetic water use efficiency was less. Yield of cotton-wheat system in terms of wheat equivalent yield (WEY) and net returns (NR) of cotton-wheat system were also reduced with the late sowing of wheat (8.4 and 6.2 %, respectively). Highest WEY (11.1-11.8 t h^{-1}) and NR (45.5-51.3x1000 Rs. ha^{-1}) of cotton-wheat system were observed with early maturing cotton genotypes (LRA-5166, LH 1556, Ankur-651, CNH-120, F-1861 and Omshankar) followed by UP2338, HD2687 and PBW343 (wheat). These findings reveal that early maturing genotypes of cotton along with normal sowing of wheat crop can improve the productivity and NR of cotton–wheat system.

***Key words*: Cotton-wheat system, early maturing cotton genotypes, LAI, wheat equivalent yield, net returns.**

INTRODUCTION

The productivity of a cropping system depends upon the yield of component crops. For maximizing the yield of a system, the phenological development of the component crops should therefore be in synchrony with the optimum environmental requirements in a given location. So, the duration of the component crops is an

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important aspect in the cropping systems, e.g. cotton-wheat system in north India (Singh *et al.* 2011). Cotton is grown under diverse climatic conditions from 9° to 31° N. It is a major cash crop and occupied about 9.4 m ha with a production of 22.3 m bales during 2008-09 (Anonymous 2011). It is largely grown as monocrop under rainfed conditions. However, about 2.0 million ha area of cotton-wheat double cropping under irrigated conditions is taken in different parts of the northwestern plains zone (e.g. south-west Punjab, Western Rajasthan, Haryana, adjoining parts of Uttar Pradesh and Madhya Pradesh). Area and productivity of cotton-wheat cropping system has however declined as reported earlier by Bhandari *et al*. 1998. This has been attributed to longer duration of cotton crop in general and partly due to lack of early maturing, short duration genotypes of cotton. Longer duration cotton crop imposes a restriction for taking wheat crop in a system mode after cotton. The yield advantage of genotypes with an earlier transition to reproductive growth as compared to the old genotypes has been observed by Wells and Meredith (1984). Further, excessive vegetative growth due to environment or genotype is often associated with reduced yield (Heitholt, 1999). Keeping this in view, an attempt was made to identify and analyze the physiological aspects of the early maturing, short duration genotypes in cotton and to evaluate them with wheat in cotton-wheat system for their suitability and productivity.

MATERIALS AND METHODS

A field experiment was conducted during 2003-2006 at the Main Research Farm of the Project Directorate for Cropping Systems Research Modipuram, Meerut in split plot design with 3 replications. Modipuram is located at 29° 4' N latitude and 77° 46' E longitude at 237 m asl. The climate is categorized as hot, dry and semi–arid subtropical with moderate summer and severe cold winters. The average annual rainfall is about 800 mm and potential evapo-transpiration of 1600 mm. The soil of the experimental field was typic Ustochrepts, sandy loam, deep and mildly alkaline (pH 8.2) with low to medium fertility (OC– 0.40 %, available P_2O_5– 32.5 Kg and K_2O – 125 Kg ha^{-1}). Twenty cotton genotypes *viz.* AAH-1, Ankur-651, CNH-120, CNH-36, F 1861, RG 8, LD 694, LH 1556, LHH-144, LRA-5166, Omshanker, SRT-1, F 846, H 1098, LD 327, PUSA 8-6, RS 2013, RS 810, Surbhi and Vikas, were grown as main plots during *kharif* 2003-2006. During *rabi* six wheat genotypes (*viz.* PBW 343, UP 2338, HD 2687, PBW 226, PBW 373 and RAJ 3765) were sown as sub plots on 20th November (normal sowing) and mid December (late sowing), after harvesting of cotton. Statistical analysis for split plot design was done as per Gomez and Gomez (1984). Observations on various morpho-physiological parameters *viz*. boll number, boll weight, plant height, biomass, leaf area, photosynthesis and transpiration were recorded at particular growth stage. Recommended package of practices for cotton and wheat were adopted. Plant samples were collected for growth studies from 1.0 m-row length in the field, except cotton hybrids where it was taken from 1.8 m row length. Samples were processed in the lab and oven dried at 70° C for dry weight observations and estimation of tuber dry matter content. Leaf area was measured using automatic leaf area meter (Model, LI-COR 3000) and LAI was calculated, while observation on photosynthesis and transpiration were taken on fully expanded upper third leaf using Photosynthetic system (Model, LI-COR 6400). Biomass and yields were recorded. Wheat equivalent yields (WEY) were calculated for all the cropping sequences to compare the yield potential of different systems following Reddy and Reddi (1995). Net returns were also calculated for each crop sequence, keeping in view the inputs and out put received from a particular system. While calculating the cost of cultivation, the rental value of land was not taken into account but the inputs given and output received in particular system were considered.

RESULTS AND DISCUSSION

Crop duration is an important character for suitability of a crop in a cropping system. The phenological requirements of the component crop should match the environmental conditions. Therefore, the first character evaluated in the twenty cotton genotypes for cotton-wheat system was the crop duration of cotton (or the days to maturity) genotypes. The duration of cotton crop showed large variation and ranged from 130 to 180 days (Table1). The genotypes AAH-1, Ankur-651, RG-8, LD-694 and CNH 120 reached harvestable maturity very

Table 1. Morpho-physiological parameters and seed cotton yield of different cotton genotypes

Genotypes	Duration (days)	Seed cotton yield (t ha^{-1})	Boll weight (g boll^{-1})	Harvested boll nos. plant^{-1}	Monopodia (Plant^{-1})	Sympodia (Plant^{-1})	Total Biomass (g plant^{-1})		LAI		Plant height (cm)
							90 DAS	120 DAS	90 DAS	120 DAS	
Early maturing cotton group											
AAH 1	130	2.05	2.68	26.5	2.13	34.17	146.2	194.9	2.36	2.07	165.4
Ankur 651	142	2.12	3.24	23.6	1.73	27.87	137.8	195.8	3.80	2.59	108.0
CNH 120	149	2.12	3.03	21.5	1.33	21.33	128.4	199.9	4.66	4.00	115.0
LD 694	139	2.34	2.92	23.9	1.80	28.87	133.5	208.4	4.46	4.47	119.7
RG 8	135	2.10	2.89	21.5	2.47	26.90	131.7	192.1	4.89	4.11	140.7
Omshankar	162	2.00	2.90	19.7	3.07	36.33	156.1	273.0	3.49	3.42	130.0
LHH 144	160	2.00	3.28	22.4	3.40	37.27	158.6	258.6	3.50	3.47	136.8
CNH 36	170	1.93	2.59	22.6	1.83	25.83	130.0	175.0	4.03	3.36	114.0
F 1861	162	2.24	3.56	21.4	2.00	33.13	169.3	203.6	5.47	4.25	138.8
LH 1556	162	2.25	2.53	24.1	1.93	27.30	151.7	214.5	5.49	3.90	169.3
LRA 5166	165	2.23	2.55	26.1	1.33	14.67	155.2	223.5	5.76	4.24	172.2
SRT 1	165	2.10	3.24	27.2	1.33	18.00	142.9	193.2	4.97	3.90	112.3
Surbhi	165	2.07	3.16	22.3	0.67	16.67	148.3	196.0	4.61	4.83	138.0
Late maturing cotton group											
F 846	170	1.90	3.18	25.2	1.90	28.33	140.0	218.3	4.80	4.64	137.3
H 1098	175	2.03	3.27	22.2	1.83	25.13	129.3	186.5	4.79	4.52	127.3
LD 327	170	1.94	3.01	24.1	2.10	31.03	128.4	173.8	4.06	4.24	116.8
Pusa 8-6	185	1.87	3.48	23.9	1.47	26.63	135.7	206.2	4.31	3.92	116.3
RS 2013	180	2.04	3.03	21.0	1.93	25.13	130.2	178.9	5.16	4.99	150.0
RS 810	180	1.81	2.92	18.0	2.33	25.37	125.7	203.1	4.36	4.38	138.0
Vikas	175	1.89	2.62	25.4	1.70	26.80	133.9	217.7	4.83	4.03	136.2
CD (P=0.05)	-	0.19	0.27	2.8	1.05	4.64	16.8	19.4	0.56	0.37	6.9

DAS= Days after sowing

early (130 and 149 days) followed by LHH-144, F 1861, LH 1556, , LRA-5166, Omshankar, SRT-1, Surbhi and CNH-36, (160-165 days). The remaining cotton genotypes (F 846, H 1098, LD 327, PUSA 8-6, RS 2013, RS 810 and Vikas) were harvested in 170 to 185 days (October end to mid November). Genotypic variations in different morphological (shoot length, number of monopods and sympods), physiological (LAI and biomass) and yield (boll number and boll weight) parameters were significant (Table 1). High vegetative growth i.e. LAI at 90 DAS (maxium LAI - 5.76) and biomass at 120 DAS (175-273 g plant $^{-1}$) was observed in early genotypes (Ankur-651, CNH 120, F 1861, RG 8, LD 694, LH 1556, LHH-144, LRA-5166 and Omshankar) as compared to late genotypes where biomass and LAI were relatively less (Table 1). Ashley *et al.* (1965) estimated that an LAI of 5.0 was necessary to sustain growth of early maturing fruit for maximum yield in an irrigated system. Similarly, Wells and Meredith (1984) found LAI of 3.9-6.3 for higher carbon assimilation rates. This also indicates a higher growth rate in early genotypes. Early canopy development is important in establishing a structure that can effectively support the reproductive period (Cathren

1999). Vertical growth (shoot length) was also higher (108-172 cm) in early genotypes as compared with late group of genotypes (116-138 cm). Early genotypes (LHH-144, Omshankar, AAH-1 and F-1861) possessed significantly higher number of sympodial branches (33-37 plant^{-1}). The seed cotton yield of different genotypes ranged from 1.81 to 2.42 t ha^{-1} (Table 1). Significantly higher seed cotton yield was observed in early genotypes (1.93 to 2.34 t ha^{-1}) than the late types (1.81 to 2.04 t ha^{-1}). Wells and Meredith (1984) also reported that the cultivars with an earlier transition to reproductive growth had greater reproductive to vegetative ratio. LD-694 gave the highest seed-cotton yield (2.34 t ha^{-1}) followed by LH-1556, F-1861 and LRA-5166 (2.23 to 2.25 t ha^{-1}). This was observed to be associated with boll number and boll weight; the two main components of seed cotton yield (Oosterhuis and Stewart 2004). Correlation coefficient was worked out among different parameters. It was observed that biomass in different genotypes was positively associated with LAI (r = 0.660*) and seed-cotton yield (r = 0.754*). Similar results were also reported in our earlier studies (Singh *et al*. 2004b, 2005 and 2007a). Data on photosynthesis (Pn), photosynthetic water use efficiency (PWUE) and photosynthetic radiation use efficiency (PRUE) presented in (Fig. 1) clearly indicate that variety CNH-36, CNH-120, RS 810, Pusa 8-6, RS-2013, Vikas, LH-1556, Surbhi, and hybrids Ankur 651, Omshanker and LHH-144 appeared physiologically more efficient in terms of Pn (28-31 µ mole CO_2 m^{-2} s^{-1}) and PWUE (2.93-4.60 m mole CO_2 mole^{-1} H_2O). Hearn and Constable (1984) also reported that the rate of net photosynthesis of individual cotton leaves is about 30 µmole CO_2 m^{-2} s^{-1}. Singh *et al*. (2004a, 2007a and 2007c) also observed genotypic variability in cotton for different physiological parameters. The PWUE was however in general negatively related to the seed-cotton yield (Fig 1B). Acevedo (1993) also reported decrease in the yield of barley with increase in WUE.

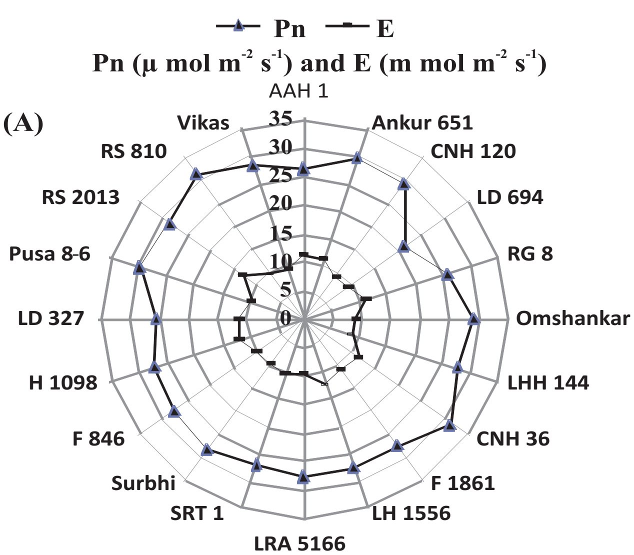

Fig. 1 (A). A: Photosynthesis (Pn) and transpiration (E) in twenty cotton genotypes

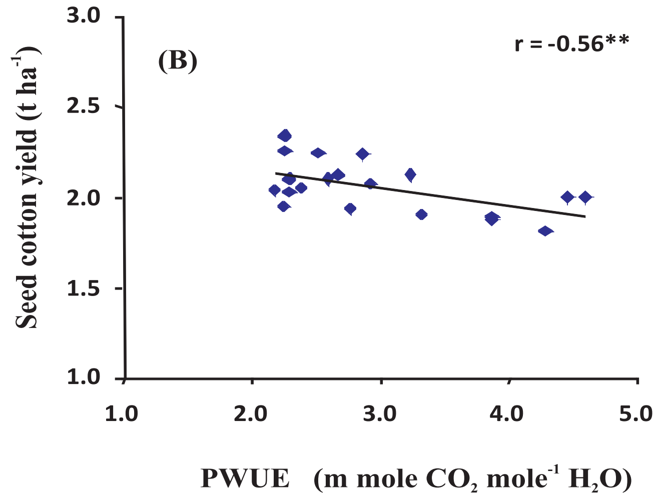

Fig. 1 (B). Relationship of seed cotton yield and photosynthetic water use efficiency (PWUE)

The six wheat genotypes were sown timely or late depending upon the duration of the cotton crops. Leaf area index (LAI) and biomass productivity in wheat linearly increased with the growth stage (Table 2). Significantly higher LAI (3.96-4.10) was observed at 90 DAS, while biomass continued to increase up to maturity (11.21-11.81) under both normal and late sown conditions. LAI was significantly reduced with late sowing of wheat at 120 DAS (13 %). Biomass also reduced with late sowing. This reduction due to late sowing is attributed to the sensitivity of development of wheat to major environmental factors - temperature and photoperiod (Slafer and Rawson 1994; Tewari and Singh 1993). Significantly higher biomass (11.6-12.0 t h^{-1}) and LAI (4.1-4.4) were recorded in UP2338, HD2687 and PBW343 than, PBW373, PBW226 and RAJ3765 (11.1-11.3 and 3.8, respectively). The grain yield of six wheat

Table 2. Grain yield, biomass and leaf area index of wheat under timely and late sown conditions after harvesting of cotton.

Wheat genotypes	Leaf area index 90 DAS			Leaf area index 120 DAS			Biomass at maturity (t ha^{-1})			Grain yield(t ha^{-1})		
	Timely	Late	Mean	Timely	Late	Mean	Timely	Late	Mean	Timely	Late	Mean
UP 2338	4.37	4.39	4.38	2.51	2.37	2.44	12.61	11.48	12.04	5.46	4.95	5.20
HD 2687	4.24	4.23	4.23	2.56	2.26	2.41	12.16	11.12	11.64	5.29	4.87	5.08
PBW 343	4.10	4.20	4.15	2.39	2.05	2.22	12.34	11.42	11.88	5.43	4.96	5.20
PBW 373	3.64	4.03	3.83	2.36	1.88	2.12	11.14	11.10	11.12	4.83	4.81	4.82
PBW 226	3.73	3.89	3.81	2.18	1.73	1.95	11.46	11.14	11.30	4.94	4.73	4.84
RAJ 3765	3.68	3.87	3.77	2.04	1.93	1.98	11.17	10.99	11.08	4.82	4.69	4.75
Mean	3.96	4.10		2.34	2.03		11.81	11.21		5.13	4.83	
CD (P=0.05)	Wheat genotype (wh geno)		0.07	Wheat genotype (wh geno)		0.07	Wheat genotype (wh geno)		0.09	Wheat genotype (wh geno)		0.04
	Sowing time (st)		0.04	Sowing time (st)		0.03	Sowing time (st)		0.81	Sowing time (st)		0.03
	wh geno x st		0.92	wh geno x st		0.06	wh geno x st		0.20	wh geno x st		0.08
	st x wh geno		0.93	st x wh geno		0.38	st x wh geno		0.17	st x wh geno		0.07

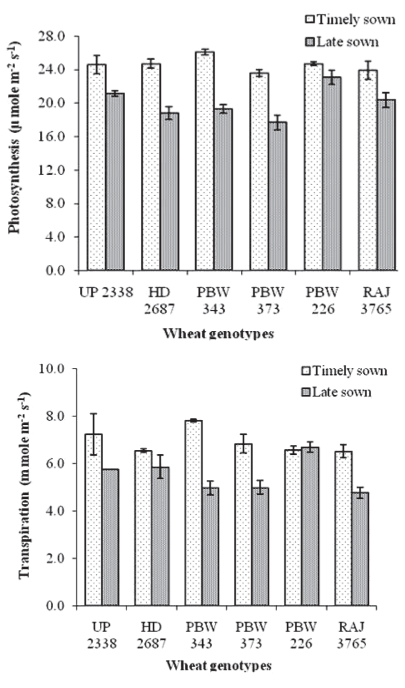

Fig. 2A. Photosynthesis rate (Pn) and transpiration rate (Tr) in different wheat genotypes under timely and late sowing conditions

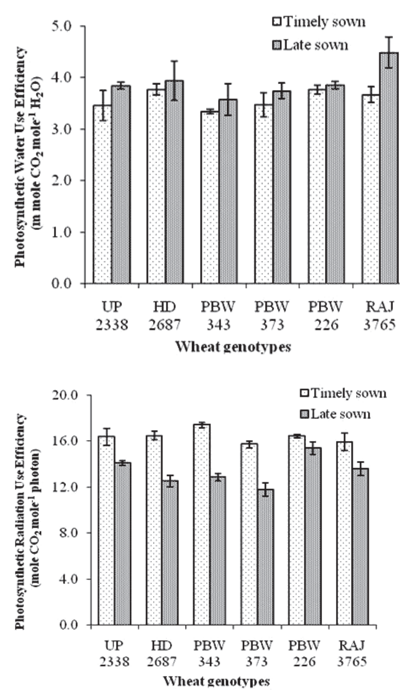

Fig. 2B. Photosynthetic radiation use efficiency (PRUE) and photosynthetic water use efficiency (PWUE) in different wheat genotypes under timely and late sowing conditions

genotypes after cotton ranged from 4.7 to 5.2 t/ha (Table 2). Significantly higher grain yield was observed in wheat genotypes UP 2338, HD 2687 and PBW 343 (5.1-5.2 t h^{-1}) as compared to PBW 373, PBW 226 and RAJ3765 (4.8 t h^{-1}). Late sowing of wheat due to late harvesting of cotton significantly reduced the wheat yield in all the genotypes (6 %). The reduction was, however, more in UP 2338, HD 2687 and PBW 343 (8-9 %) as compared

Table 3. Wheat equivalent yield (t ha^{-1}) and net return (Rs. ha^{-1}) from different component genotypes in cotton-wheat system.

Cotton Genotype (CG)	Wheat equivalent yield (t ha^{-1})							Net return (Rs. ha^{-1})						
	Wheat genotypes (WG)						Mean	Wheat genotypes (WG)						Mean
	UP 2338	HD 2687	PBW 343	PBW 373	PBW 226	RAJ 3765		UP 2338	HD 2687	PBW 343	PBW 373	PBW 226	RAJ 3765	
Early maturing cotton group														
AAH 1	10.25	10.17	10.17	9.57	9.71	9.62	9.92	38390	37544	37453	32180	33600	32628	35299
Ankur-651	11.84	11.84	11.84	11.18	11.25	11.18	11.52	45938	45762	45631	39854	40645	39886	42953
Omshankar	11.53	11.09	11.36	10.70	11.12	10.76	11.10	46646	42943	46000	38651	41195	38651	42348
LHH 144	11.08	10.86	11.07	10.65	10.71	10.37	10.79	43400	43400	44993	37184	39091	37191	40877
CNH 36	11.01	10.98	11.05	10.37	10.42	10.40	10.71	43521	43142	43594	37653	38184	37933	40671
CNH 120	11.68	11.58	11.71	11.12	11.20	11.21	11.42	46943	45833	46761	41480	42619	42625	44377
LH 1556	11.79	11.50	11.66	10.97	11.05	10.85	11.31	51322	49933	50049	45027	46152	44550	47839
F 1861	11.68	11.46	11.75	10.94	11.18	10.98	11.33	49894	48250	50130	43848	45400	44132	46942
SRT 1	11.28	11.04	11.17	10.66	10.77	10.77	10.95	44141	41669	42602	38217	39478	39310	40903
Surbhi	11.14	11.05	11.35	10.98	10.85	10.90	11.05	42718	41616	44072	41059	40104	40450	41670
LRA 5166	11.83	11.70	11.81	11.35	11.36	11.27	11.55	48141	46689	47443	43580	43993	42983	45472
LD 694	11.17	11.03	11.07	10.31	10.44	10.23	10.71	44932	43536	43575	38807	39516	38512	41480
RG 8	10.52	10.31	10.45	9.88	10.00	9.86	10.17	41013	39531	40242	35632	37018	36180	38269
Mean	11.29	11.12	11.27	10.67	10.77	10.65		45154	43834	44811	39475	40538	39618	
Late maturing cotton group														
F 846	10.34	10.22	10.34	10.17	10.07	9.91	10.18	44246	43067	44202	42785	42311	42191	43134
RS 2013	10.73	10.66	10.79	10.40	10.51	10.43	10.59	43155	43617	43325	40857	41248	40577	42130
RS 810	9.74	9.72	9.78	9.76	9.66	9.56	9.70	38777	37981	37944	37622	38596	37418	38056
H 1098	10.78	10.79	10.82	10.75	10.73	10.70	10.76	41201	41128	41297	40898	40754	40427	40951
Vikas	9.83	9.83	9.80	9.67	9.57	9.61	9.72	39105	38655	39538	37528	37902	37654	38397
Pusa 8-6	9.98	9.90	9.91	9.96	9.69	9.80	9.87	42116	41907	41956	42130	42256	42246	42102
LD 327	9.68	9.39	9.75	9.44	9.35	9.27	9.48	32875	32592	33559	32989	32588	31500	32684
Mean	10.15	10.07	10.17	10.02	9.94	9.90		40211	39850	40260	39258	39379	38859	
Overall mean	10.72	10.60	10.72	10.34	10.36	10.27		42682	41842	42535	39367	39959	39238	
CD (P=0.05)	CG	WG	CG x WG	WG x CG				CG	WG	CG x WG	WG x CG			
	0.89	0.04	0.16	0.91				7215	282	1262	7306			

to PBW 226 and RAJ3765 (2.6-4.3 %) but no reduction in yield was noticed in PBW 373 with late sowing (Table 2). Singh *et al.* (2005 and 2007b) also reported the genotypic variability and yield reduction with the late sowing of wheat.

Grain yield was observed to be associated with LAI ($r = 0.695^*$) which were significantly higher in UP2338, PBW343 and HD2687. The association between biomass and LAI was also positive ($r = 0.695^*$). Variations were also recorded in various physiological parameters in wheat. Late sowing of wheat significantly reduced Pn (22 %), transpiration rate (Tr) (28 %) and PRUE (20 %). Reduction in these parameters was observed in all the genotypes except PBW-226 (Fig. 2). On the other hand, PWUE increased (9 %) under late sown conditions. Variety UP-2338 and PBW226 appeared physiologically more efficient in terms of photosynthesis (22.83 and 23.90 µ mole CO_2 m^{-2} s^{-1}, respectively). Physiological WUE (m mole CO_2 $mole^{-1}$ H_2O) was higher in RAJ3765 (4.12) and HD 2687 (3.81) than other genotypes (Fig. 2). This gets support from the findings of Singh *et al.* (2008).

The cotton-wheat system yield in terms of wheat equivalent yield (WEY) and net returns of cotton-wheat system were also reduced with the late sowing (Table 3) of wheat (8.4 and 6.2 %, respectively). More reduction in WEY and net returns was observed with genotypes UP 2338, HD 2687 and PBW 343 (9-10 %). Highest WEY (11.1-11.8 t h^{-1}) and net returns (45.5-51.3x1000 Rs. ha^{-1}) of cotton-wheat system were observed with early maturing cotton genotypes (LRA-5166, LH 1556, Ankur-651, CNH-120, F-1861 and Omshankar) followed by UP2338, HD2687 and PBW343 (wheat) (Table 3). Performance of the above cotton genotypes in cotton-wheat system with PBW373, PBW226 and RAJ3765 (wheat) was relatively better than the other cotton genotypes as revealed by the WEY (10.7-11.6 t h^{-1}) and net returns (38.6-46.2x1000 Rs. ha^{-1}). Singh *et al.* (2008) also observed that cotton genotypes like Ankur 651 and LD 694 were most suitable for cotton-wheat system in terms of duration, growth, yield and productivity. Overall system's productivity (WEY) and net returns were also higher with these genotypes with HD 2687 wheat. Based on the above study, the optimum cotton crop duration for maximizing the productivity of cotton-wheat system (WEY and NR) appeared to be about 150-160 days (Fig 3). Based on the above findings, it may be concluded that the productivity and the net returns of cotton–wheat system may be increased with the improved and early maturing genotypes of cotton (LRA-5166, LH 1556, Ankur-651, CNH-120, F-1861 and Omshankar) and wheat (UP2338, HD2687 and PBW343) with normal sowing.

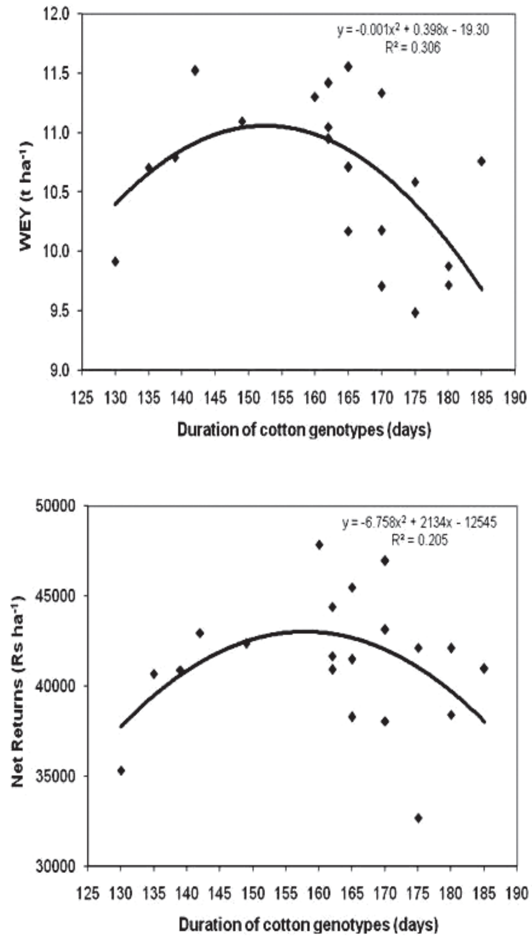

Fig. 3. Maximization of the cotton–wheat system productivity parameters i.e. wheat equivalent yield (t ha^{-1}) and net returns (Rs ha^{-1}) from twenty cotton genotypes through an optimum duration of cotton crop

In the northern Indian plains zone cotton is usually sown in the first fortnight of May. Most of the genotypes are of longer duration which mature by October end to mid November. After that, harvesting and field preparation delays the planting of wheat up to mid December. Therefore, the duration of cotton crop imposes a limitation on the optimal development of wheat. Short duration genotypes in different crops are invariably associated with lesser yields as compared to the longer duration crops. However, under north Indian conditions longer duration of cotton crop also leads to excessive vegetative growth and therefore lower harvest index. Therefore, short duration cotton genotypes can very well fit into the system and it emerged as the foremost character for improving the productivity of the cotton-wheat system in the northwestern plains zone. The cotton-wheat system with above genotypes may occupy a significant position under the changing agricultural scenario of declining water table under northern zones of India.

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