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Opinion Article

Exploit Physiological Efficiency to Overcome Planting Time Barrier in Wheat and Develop Varieties Suitable for per day Productivity

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Abstract

Varieties evaluated by All India Coordinated Research Programme on Wheat and Barley (AICRPWB)during the period 2000-23 were assessed in four zones of Indian plains. The purpose was to test whether the timely and late sown genotypes were really exclusive for these two production conditions. Physiological efficiency was used as the primary distinguishing tool in Advance Varietal Yield Trials of timely sown and late sown conditions. Application of six physiological parameters made it amply clear that most of the varieties were physiologically efficient in overcoming the hurdles of planting time in three zones namely North Easter Plains Zone (NEPZ), Central Zone (CZ) and Peninsular Zone (PZ). Situation was quite different in the most productive wheat land of the country i.e. North Western Plains Zone (NWPZ). Although majority of the timely-sown varieties did qualify for late-sown condition in this zone but only few late-sown varieties could meet the efficiency level of timely-sown condition. This analysis suggests that the pre-released varieties of both sowing conditions should be tested together under both sowing dates against the popular checks of both sowing conditions. Assessment on the basis of per day productivity has also suggested as an alternate pathway. The predictors have been suggested for each zone to formulate an ideotype-based breeding strategy.

Keywords: Per day yield, physiological efficiency, production conditions, wheat productivity

1. Introduction

In India, wheat is cultivated in diverse production environments. The irrigated wheat is grown mainly in two production conditions i.e. timely-sown (TS) and late-sown (LS). The recommended varieties are also specific for each production condition. Prevalence of late-sown wheat (LSW) in India depends upon the prevailing cropping system of the zone and it warrants genotypes of short maturity duration. The timely-sown wheat (TSW) has longer maturity duration and it is planted in the first fortnight of November whereas LSW is sown 25-30 days thereafter. In the era of GEC, the crop season variations are turning stronger and often need is felt to have varieties which are capable of adjusting productivity in accordance with the maturity duration permitted under any planting time. Given the increasing unpredictability in seasonal patterns due to Global Environment Change (GEC), adaptable wheat varieties are more relevant than ever. It is envisaged that instead of different categories of wheat, it would be easier for the farmers to grow only one type of wheat. It requires specifically bred genotypes that are physiologically efficient to adjust the crop phenology in accordance with the climatic variations. If the growth conditions are good, such genotypes should be able to draw the benefit of extended crop duration and when climate is harsh or the sowing gets delayed due to weather or crop system compulsions, the same genotype should curtail the crop duration accordingly. In the era of climate change, it is envisaged that crop breeding should shift its emphasis from per crop to per-day productivity (Swaminathan and Kesvan, 2012). Undoubtedly, such genotypes are expected to excel in physiological efficiency, per day productivity and possess inherent plasticity under varying environments.

To cater specific varietal need of the farmers, AICRPWB conducts yield trials in different regions of the country namely WPZ, NEPZ, CZ and PZ. Although trials are also conducted for the Northern Hills zone (NHZ) but this zone was not included in the study as the ecology is quite different in the hills. This study has examined released bread wheat varieties evaluated by this national system in two categories of Advance Varietal Trials (TS and LS) during the period 2000-23. The genotypes were examined in detail for yield and the related economic traits. The motive was to assess whether varieties of these two production conditions are really specific for the planting time or they can be utilized for varying sowing conditions. If so, whether it happens only in some region or it can be applied across all zones. Varietal distinctions in this study have been done on the basis of physiological efficiency. This tool has been applied to differentiate wheat varieties of NWPZ (Mohan *et al.*, 2004; Kavita *et al.*, 2018). AICRPWB does evaluate the pipeline varieties for altered sowing conditions under the resource management programme but the focus is only to test TSW for early sowing and LSW for very-late sowing.

It is evident that in comparison to LSW, the TSW would be taller, have larger vegetative and reproductive phases, longer maturity duration, better thousand-grain size (TGW) and higher grain yield (Table 1).The yield loss in LSWcan be more than 15% in the Indo-Gangetic plains i.e. IGP (NWPZ: 18.1 %; NEPZ: 15.3 %). In the central-peninsular India (CPI), the yield loss in LSW drops to less than 15 % (CZ: 14.4 %; PZ: 10.6 %). Similar differences in productivity and related economic traits had been reported in different wheat zones of India (Mohan *et al.*, 2021, 2022).

Table 1: Comparison of timely and late-sown wheat in different wheat zones (Period 2000-23)

Parameter	NWPZ		NEPZ		CZ		PZ	
	TS (86)	LS (73)	TS (116)	LS (51)	TS (54)	LS (57)	TS (54)	LS (46)
Grain yield (q/ha)	54.3***	44.5	43.4***	36.8	52.5***	44.8	45.2	40.4
Maturity days	144***	122	123***	107	118***	107	106***	98.2
Plant height (cm)	96.4***	89.7	93.5***	85.6	89.9***	82.3	82.2	80.7
Days to heading	97.2***	82.7	80.1***	67.8	68.0***	62.7	61.0***	56.5
Grain filling days	46.4***	39.7	43.1***	39.0	50.0***	43.8	44.7***	41.6
1000 grain weight (g)	39.6***	36.4	40.9***	37.5	43.8***	40.3	42.0***	39.7

Figure in parenthesis indicate number of observations

*, **, ***indicates significance at P 0.05, 0.01 and 0.001, respectively.

This analysis highlighted that the yield reduction in LSW was minimal in PZ (7.1 %) and so was the reduction in maturity duration (10.6 %). Crop duration was also shortest in this zone. In CZ, yield reduction was slightly higher in yield (10.3 %) and drop in maturity duration was 14.3 %. In comparison, yield decline in late plating was highest in NWPZ (14.8%). Overall maturity period and the reduction in crop duration under late planting were also highest in this zone (18.1 %). In the adjoining NEPZ, yield decline in LSW was 13.7 8% in yield and 15.3 % in crop duration. It underlines that the percent yield reduction in LSW commensurate with the reduction percentage in maturity duration.

2. Comparison of physiological efficiency

The two types of wheat i.e. TSW and LSW were further compared for the physiological efficiency and six parameters were computed in this exercise. Per-day productivity (PDP) was derived as ratio between the mean grain yield and days to maturity (DM). Height gain rate (HGR) was calculated as ratio between plant height and days to heading (vegetative period). Grain formation rate (GFR) denoted number of grain formed per day during the vegetative period. Grain growth rate (GDR) was a ratio between TGW and days to grain filling. Yield fill rate (YFR) represented the yield accumulation per day during the reproductive period. Ripening-maturity index

(RMI) denoted percentage of the ripening period in total maturity duration. Comparison between TSW and LSW was done by "t-test" at probability level 0.01.

This investigation revealed that although yield and crop expression were always better in TSW, the LSW also had an edge in several aspects of physiological efficiency (Table 2). In NWPZ; LSW was better than TSW in HGR, GFR and GGR whereas TSW was more efficient in PDP and YFR. In comparison, this difference was reduced to just two parameters in PZ where TSW was better in PDP and LSW was more efficient in HGR. This analysis clearly indicates that even when TSWis taller in comparison to LSW but in most of the cases, height in LSW is actually attained at a faster rate in comparison to TSW. Similarly, even if TSW has better grain bearing, grains are formed at higher rate in LSW of IGP. This region exhibits superiority over LSW in YFR also. No doubt, grains are always bolder in TSW but LSW has an edge in GGR at least in NWPZ and CZ. This comparison also makes it clear that during the whole life span, proportionate grain filling duration in LSW can be higher than TSW in NEPZ whereas it can just be the opposite in CZ. All this signifies that the advantage or disadvantage in physiological efficiency differ zone wise and trait-wise.

Table 2: Comparison of physiological efficiency between timely-sown and late-sown wheat

Parameter	NWPZ		NEPZ		CZ		PZ	
	TSW (86)	LSW (73)	TSW (116)	LSW (51)	TSW (54)	LSW (57)	TSW (54)	LSW (46)
Per day productivity(kg/ha)	37.8***	36.4	35.2*	34.5	44.5***	42.0	42.8**	41.2
Height gain rate (cm)	0.99	1.09***	1.17	1.26***	1.33	1.31	1.36	1.43***
Ripening-maturity index (%)	32.5	32.3	34.7	36.5***	42.4**	41.1	42.0	41.9
Grain formation rate (grains)	141	148***	132	145***	177	178	178	181
Grain growth rate GR (g)	0.86	0.92***	0.95	0.96	0.88	0.92***	0.94	0.96
Yield filling rate (kg)	117***	112	101***	95	105*	102	101*	98

Figure in parenthesis indicate number of observations

*, **, ***indicates significance at P 0.05, 0.01 and 0.001, respectively

3. Comparison of variations in growth rate

When physiological efficiency registers over lapping, it will always be useful if TSW and LSW are examined to chalk out any commonality between the two categories of wheat. It was observed that even though significant differences occurred between TSW and LSW, some similarity can always be traced between the genotypes of two categories of wheat(Table 3). Taking into consideration all six parameters, it was observed that 73.3% of TSW in NWPZ was as efficient as LSW whereas only 38.4 % of LSW could matchthe TSW in this zone. In contrast; 90.2 % of LSW in NEPZ expressed similar efficiency level as that of TSW. In this zone, TSW could also register the similarity level of LSW in 65.5 %of cases. In CZ, the physiological efficiency match was 63.0 % in TSW and 79.6 % in LSW. PZ was a unique case where efficiency difference was minimal i.e. 94.5 % in TSW and 82.6 % in LSW. It gives a strong indication that there is lot of similarity in physiological efficiency between the TSW and LSW. However, the difference in magnitude of resemblance can vary in different regions and in different parameters. In IGP, this type of commonality is tilted towards TSW in NWPZ and towards LSW in NEPZ. In CPI, the percentage is comparable in both the zones i.e.64 to 70 % in CZ and 83 to 95 % in PZ.

4. Identification of suitable varieties for both sowing schedules

After finding that the TSW can be as efficient as of LSW and *vice versa* in physiological parameters, another attempt was made to earmark those varieties which were suitable for alternate sowings. Further, matching frequency was derived for each variety which denoted the ratio between the numbers of years the efficiency matched out of the total years of its testing. The varieties with suitability percentage below 50% were considered unfit for the alternate sowings (Table 4).There were certain varieties which had undergone only one year testing during the study period like HD 3336 (TSW) in NWPZ, HD 3388 (TSW) and HDW 316 (LSW) in NEPZ, NWS 2194 (TSW) in CZ and

Table 3: Range of physiological parameters in genotypes of timely and late sown wheats

Zone	Category	PDP	HGR	GGR	GFR	YFR	RMI
NWPZ	TSW	31.7–44.2	0.83–1.10	0.73–1.00	106–169	89–137	27.4–40.0
	LSW	31.1–43.6	0.91–1.19	0.79–1.05	121–178	91–138	28.3–37.8
NEPZ	TSW	28.9–41.1	0.94–1.42	0.77–1.16	095–171	77–126	28.9–41.8
	LSW	27.7–40.5	1.09–1.43	0.79–1.11	111–176	74–119	31.8–41.9
CZ	TSW	37.1–51.8	1.18–1.54	0.74–0.98	144–219	90–131	35.9–47.9
	LSW	35.4–49.5	1.15–1.45	0.80–1.11	146–218	78–125	36.0–45.4
PZ	TSW	34.2–48.2	1.20–1.59	0.80–1.19	148–223	76–119	37.0–46.3
	LSW	31.0–48.4	1.19–1.58	0.81–1.11	148–251	76–128	37.2–47.4

MP 1375 (TSW) in PZ, hence they were excluded in the final analysis.

In this comparison, it was observed that in NWPZ, there were only two timely-sown varieties out of 12, which could be considered unfit of late-sowing. In contrast, the late-sown varsities varieties of this region presented a different picture. Out of 11, seven varieties could be rated unsuitable for the alternate i.e. timely sowing. Situation was almost same in timely-sown varieties of NEPZ as out of 18, only three varieties were found unsuitable for late sowing. However the situation differed when late sown varieties were examined for the alternate sowing as every

Table 4: Wheat varieties suitable for alternate sowing

Zone	Category	Highly suitable (≥ 75%)	Moderate suitable (50 to 75%)	Unsuitable (Below 50 %)
NWPZ	TSW	HD 2967 (14), HD 3086 (11), WH 1105 (10), DBW 187 (4), DBW 222 (5), DPW 621-50 (8), DBW 88 (8), HD 3226 (2), PBW 862 (2)	PBW 550 (8)	DBW17 (8),PBW 502 (4)
	LSW	DBW 71 (2), DBW 590 (7)	HD 3059 (12), PBW 752 (2)	WH 1021 (14), WH 1024 (9), DBW 173 (7), DBW 90 (6), DBW 16 (5), PBW 771 (5), JKW 261 (3)
NEPZ	TSW	K 307 (13), DBW 39 (12), HD 2967 (10), K 1006 (6), HD 3249 (5), CBW 38 (2), DBW 222 (2), NW 5054 (2), PBW 443 (2), RAJ 4120 (2), RAJ 4229 (2)	K 9107 (9), DBW 187 (6), HD 3086 (3), PBW 826 (2)	HD 2733 (20), PBW343 (11), HD 2824 (5)
	LSW	NW 2036 (13), DBW 14 (13), HI 1663 (6), HD 2985 (4), HD 3118 (3), DBW 107 (3)	HW 2045 (4)	NIL
CZ	TSW	GW366 (4)	GW 322 (21), HI 1544 (14), GW 273 (3), HI 1650 (2), MACS 6768 (2)	GW 513 (3), HI 1636 (3)
	LSW	HD 2864 (13), HD 2932 (12), MP 3336 (7), HI 1634 (3)	MP 1203 (2)	MP 4010 (16), CG 1029 (4)
PZ	TSW	MACS 6222(15), GW 322 (13), MACS 6478 (7), NIAW 917 (6), RAJ 4037 (6), DBW 168 (3), UAS 304 (3)	Nil	NIL
	LSW	HD 2932 (14), RAJ 4083 (15), HD 3090 (7), AKAW 4627 (2), PBW 533 (2)	HI 1633 (4)	Nil

* Varieties evaluated for only one year not included

* Figure in the parenthesis indicate number of observations

late-sown varieties of NEPZ was found suitable for timely planting in this region. In CZ, majority of the timely-sown varieties could be rated moderately suitable for late sowing as well. Situation was much better in the late-sown category as out of 7, only three varieties failed to meet the physiological standards of timely-sown genotypes. Situation was highly encouraging in PZ as almost every genotype was suitable for the alternate sowing. It underlines that in a region where climate conditions are good for crop growth, as noticed in NWPZ, the late-sown varieties generally don't match the physiological efficiency standards of the timely-sown varieties. In all other zones, possibilities exist to identify varieties which can surpass the sowing time distinctions. This exercise highlights that developing varieties for specific production condition can be a necessity in NWPZ but for other plain areas of the country, possibilities exist for identifying the wheat varieties suitable for alternate sowing.

5. Per day productivity

In a scenario when varieties become non-specific to the planting time, it will be highly beneficial if varieties are developed on the basis of per-day productivity. To explore this possibility, all common entries with matching physiological efficiency were analyzed for the key plant attributes which could play defining role in per-day productivity. In this exercise, the selected data of both production conditions was standardized separately and regression analysis was applied to the pooled data taking into account the multi-collinearity, residuals and standardized residuals diagnostic factors into account. Step-down regression analysis was done to ear-mark the key attributes suitable for per-day productivity. The key factors were then regressed against grain yield to understand their effect on grain yield. In this exercise, some parameters which were derived from yield like GFR and YFR were not included as they were straightway derived from the yield itself. Days to gain filling was also omitted as it was derived from days to maturity and days to heading which were already included in the analysis. The key characters which expressed strong relationship with per day productivity varied zone-wise but the only common factor (except PZ) was TGW and rate of height increase whereas RMI was nowhere amongst key components. The key traits that regulated per-day productivity were TGW and HGR in NWPZ and CZ; DH, DM, TGW, HGR and GGR in NEPZ. In PZ, it was only the HT which defined per-day productivity. All these traits were also regressed against grain yield and highly significant R^2 could be recorded in all zones (NWPZ: 0.39***; NEPZ: 0.38***; CZ: 0.12**; PZ: 0.27***). It underlines that if varieties are developed for per-day productivity in accordance with the specified key components, prospects will be high to harness highly significant improvement in the grain yield. The relationship between crop growth indices and grain yield is usually positive (Mohan *et al.*, 2004; Ihsan *et al.*, 2016). In this backdrop it is logical to presume that the growth indices t can be good indicators of wheat productivity.

6. Way forward

The Indian wheat research programme carries huge workload and faces big challenges. Catering the varietal need of several diverse production conditions is not an easy task. The challenge to improvise the genetic gain mounts the pressure further (Rajaram and Braun, 2008;

Table 5: Key characteristics for per day productivity

Parameters and characteristics	Beta value of key traits in per day productivity			
	NWPZ (91)	**NEPZ (123)**	**CZ (74)**	**PZ (90)**
Beta value of key traits				
Plant height	-	-	-	0.32**
Days to heading	-	2.32**	-	-
Days to maturity	-	-1.86**	-	-
1000 grain weight	0.51***	1.81***	0.22*	-
Height gain rate	0.31***	0.23***	0.32**	-
Ripening maturity index	-	-	-	-
Grain growth rate	-	-1.78**	-	-
Coefficient of determination	0.46***	0.23***	0.19**	0.10**

Figure in parenthesis denotes number of entries

*, **, *** indicates significance at P 0.05, 0.01 and 0.001, respectively

Hanif *et al.,* 2021). There is need to balance this task and make it demand driven (Shoran *et al.*, 1998; Mohan *et al.*, 2001). In addition, the financial resources allocated for wheat research have also to be utilized judiciously. This study has underlined that there is need to shed the extra baggage which can easily be minimised by developing and recommending the varieties which can be useful for irrigated condition under flexible showing schedules. Varieties common for timely and late sowings have been released in the past and they had been very popular amongst the farmers. Cultivars like UP 2338 in NWPZ and LOK 1 in CZ have been carrying this distinction. Sonalika is another unique case as it had been used as check under timely as well as late sowing conditions throughout the country. Even in present times, certain timely-sown varieties of NWPZ (HD 3086, DBW 187) have performed very well in the early-sown trial i.e. HYPT. There are many rainfed varieties which give equally good productivity when compared to specified varieties of restricted irrigation (Mohan *et al.*, 2024). Farmers in central-peninsular India are not very particular about the sowing time of the varieties and they often plant them according to the prevailing farm conditions. The most essential feature for such regions is the crop phenology (Ihsan *et al.*, 2016; Sattar *et al.*, 2023). If varieties mature within 110-120 days, they can fit under any sowing schedule. This investigation suggests that varietal specificity for sowing time is most essential in NWPZ and less critical in other zones of the country. In NWPZ also, the restriction is mostly on the late-sown varieties. Majority of the timely-sown varieties of this region can fit-in for late planting. In NEPZ and PZ, The late-sown varieties can be tried for timely sowing as well. At least two-third of timely-sown varieties of each zone can also be tried in late sowing. In this background, there is a need to relook the varietal development and evaluation strategy adopted by the AICRPWB. For validate this new ideology, it will be proper if the pre-released varieties of timely and late sowings are evaluated together in a common trial where popular varieties of both production conditions are included as check. Sowing of this trial should be done in the two sowing dates under question. If a test entry performs better than the recommended checks under both sowing dates, it can be recommended for both the sowing dates. An alternate pathway is the breeding for per-day productivity. The key components suggested for this approach can be meaningful for ideotype-based breeding. The key factor pointed out for this type of breeding will help in developing wheat varieties which can overcome the planting time barrier and also checkmate the vagaries of climate change.

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Author contributions

The review was written and enriched by DM, SS and AJ. All authors read, edited, and approved the final manuscript.

Conflict of interest

The authors declare no conflict of interest.

Ethical Approval

The article doesn't contain any study involving ethical approval.

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No

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