Phenological variations in early planting of wheat breeding lines and identification of markers by GWAS

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ABSTRACT

Over the last fifty years, the wheat improvement programs and releasing commercial wheat varieties in south Asia has been successful in developing countries. However, a decrease in annual genetic gain for yield has been observed attributed to global warming. Being a winter cereal, wheat needs substantial amount of heat tolerance both at early growth stages, immediately after planting and at terminal grain filling stage. Significant variation for terminal heat tolerance exists in the native wheat gene pool. Likewise, early sowing may allow to select early heat tolerant genotypes along with longer phenology to escape terminal heat stresses. A study was conducted to map early heat tolerance at BISA farm, Ludhiana in 2017-18 and 2018-19 seasons. A total of six hundred wheat lines were planted seventeen days earlier than timely planting for 2017-18 season and, another set of six hundred lines were planted 24 days earlier than timely planting for 2018-19 season. Trial design was alpha lattice with two replications. Several agro-morphological and physiological traits were evaluated. Yield was significantly increased but the TGW was shown to be varied in early planting. Most of the early planted genotypes matured one week earlier in 2017-18 season and two weeks earlier in 2018-19 season than normal planting, pertaining that the addition of phenological times is dissecting its effect on other phenological dates. Genome Wide Association Studies (GWAS) identified several significant SNP markers associated with early heat tolerance. The results open new avenue to further study QTLs association in details with adaptation to early planting through phenological genes like vernalization, photoperiod, reduced height and earliness per se.

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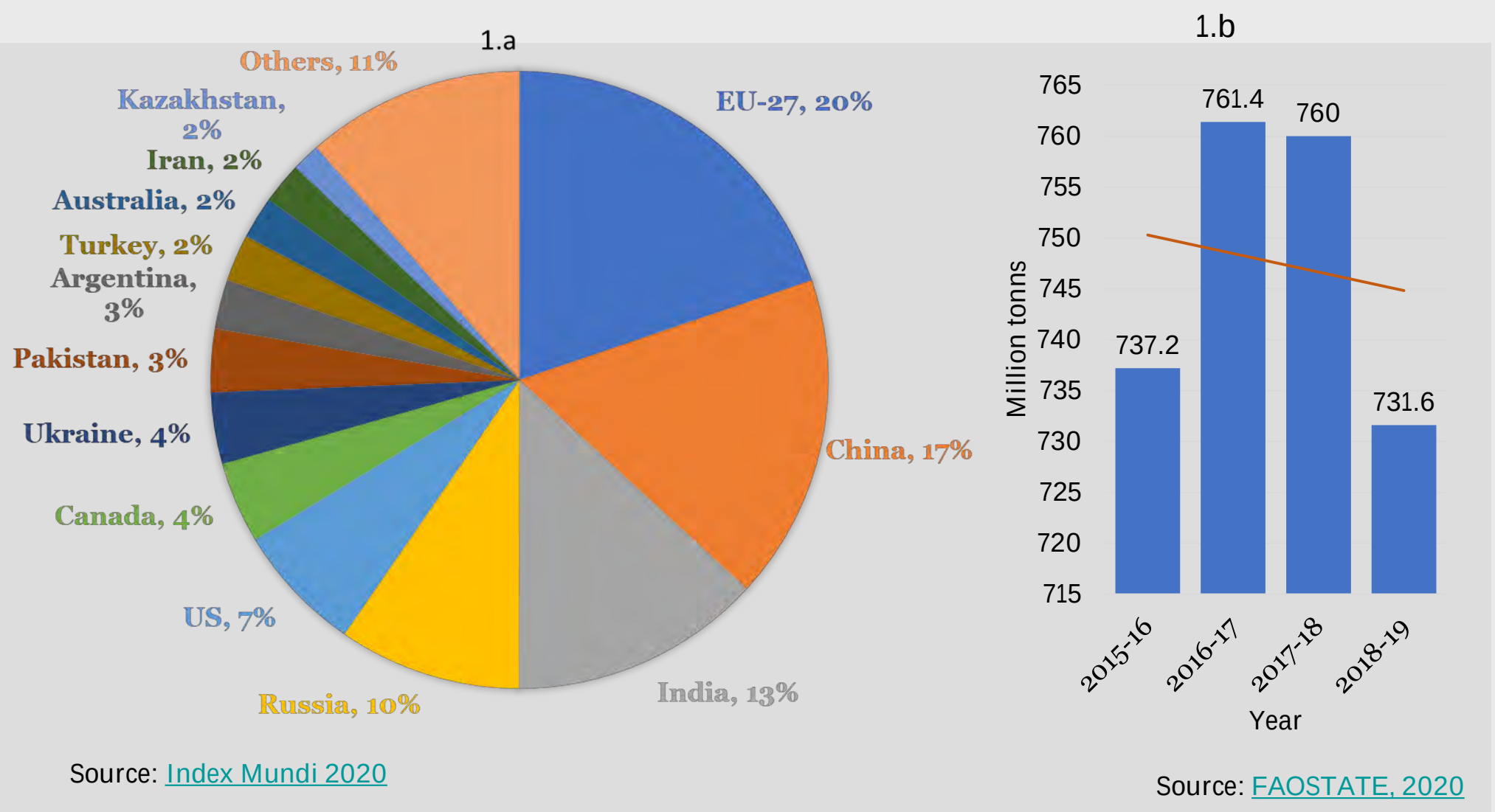
INTRODUCTION



Source: Index Mundi 2020

Source: FAOSTATE, 2020

Figure 1: a) The Asia-Pacific wheat production is mainly dominated by China and India
b) Global what yield is in decreasing trend from 2015 to 2019 seasons.

- 1ºC increase in temperature, cause 6 ± 2.9% wheat yield loss globally (Zhao et al., 2017)
- Water availability is expected to decline significantly (Singh et al., 2007)

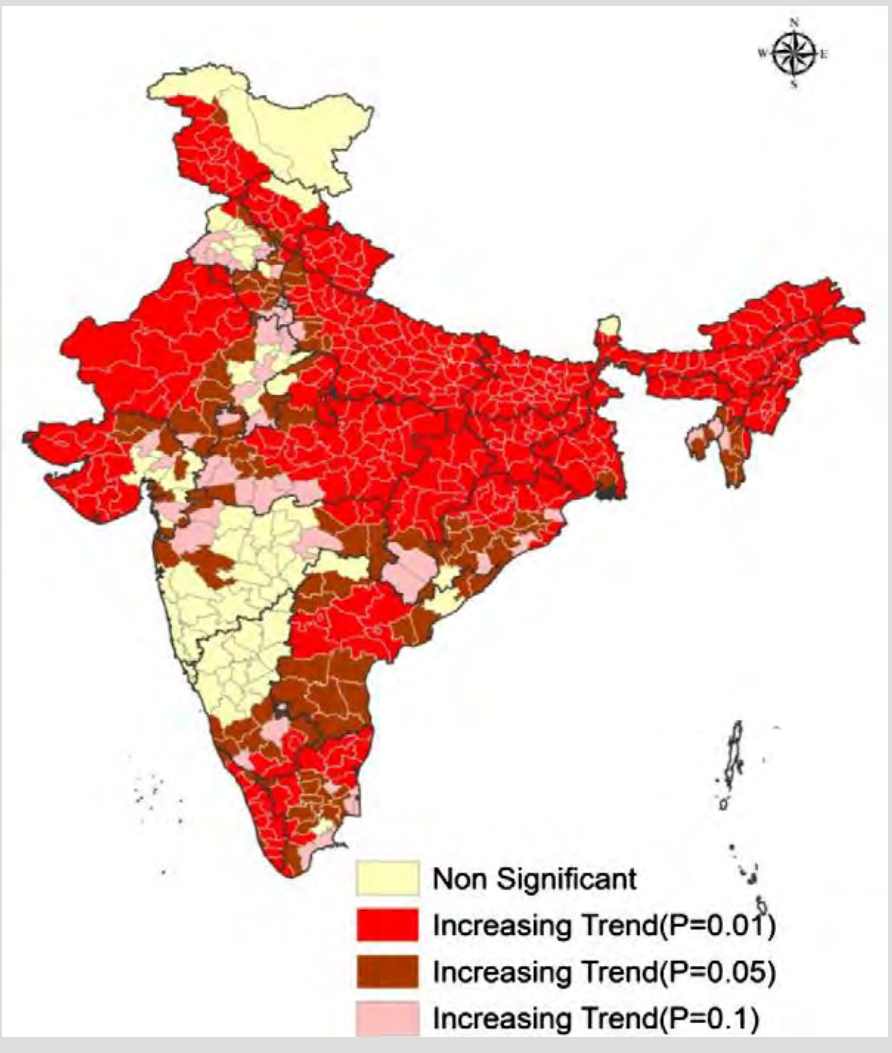


Figure 2: Increasing trends of minimum rabi temperature over India from 1971 to 2009 (Rao et al., 2014)

Figure 3: Indo Gangetic plain (IGP) is the breadbasket of India which provides 15% of global wheat production.

51% of IGP is under threat to be transformed as heat stressed, short season, sub-optimal wheat production zone by 2050 (Ortiz et al., 2008)

METHODS AND MATERIALS

Season: 2017-18
Genotypes : 54 lines + 6 checks
Entry per trial : 60
Total Trials : 10
Replications : 2
Sowing conditions : 2
(Early and Timely planting)
Total plots : 1200 × 2

Season: 2018-19
Genotypes : 53 lines + 7 checks
Entry per trial : 60
Total Trials : 10
Replications : 2
Sowing conditions : 2
(Early and Timely planting)
Total plots: 1200 × 2

Figure 4: Aerial view of research trial in two seasons at BISA farm, Ludhiana, Punjab, India.

Software

R 4.0.2 (2020)-Open source

R packages:

- Metan 1.8.0: An R package for multi-environment trial analysis (Olivoto and Alessandro, 2020)
- tidyverse (Hayes et al., 2019)
- GAPIT 3 : Genome association and prediction integrated tool (Zhang et al., 2012)

RESULTS

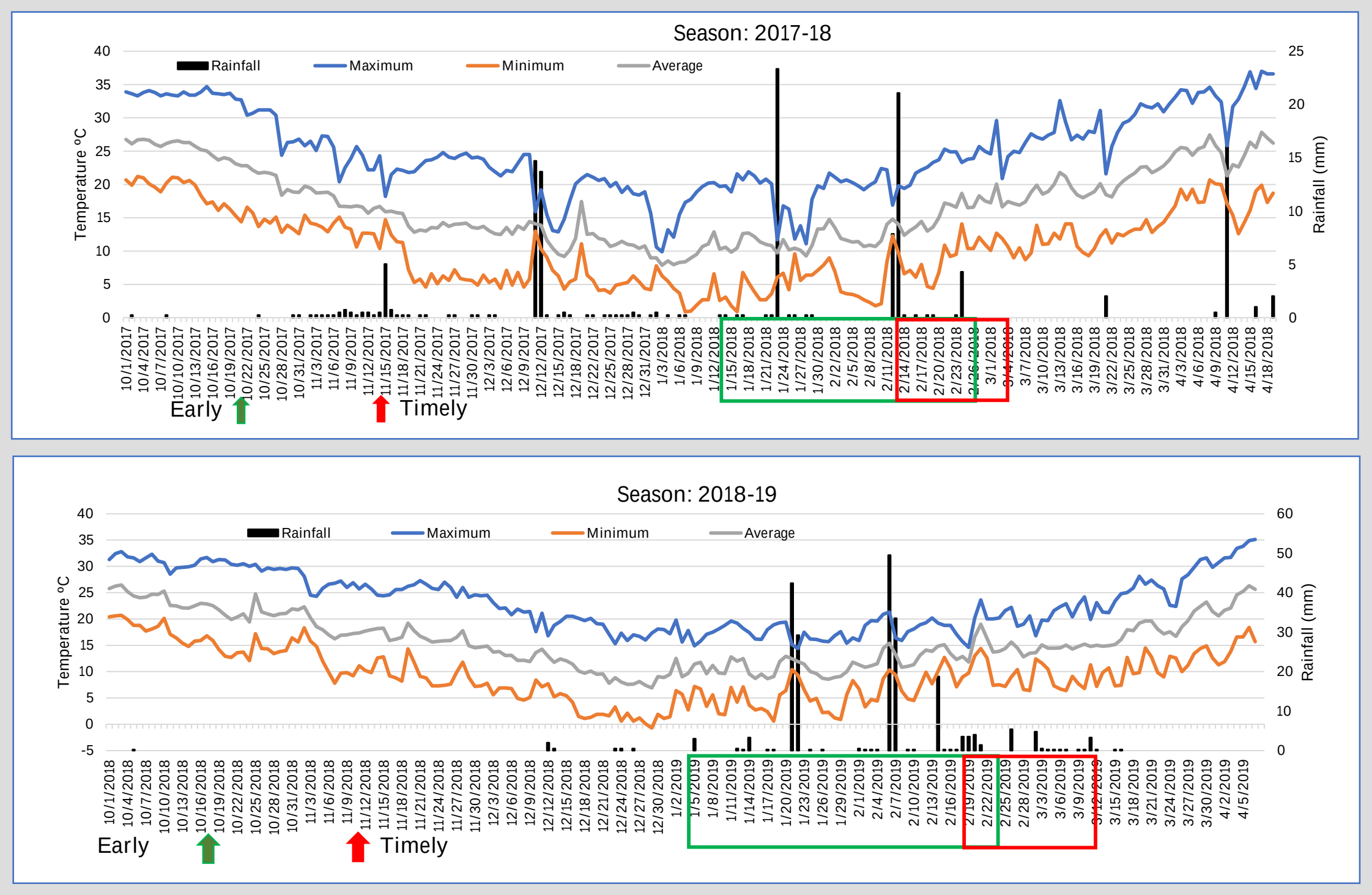


Figure 5: Variation of heading days in planting time shifting, showing with seasonal weather parameters. Early planting (green) increased the variation in heading days compared to timely planting (red).

Figure 6: Trait variations observed in both the seasons

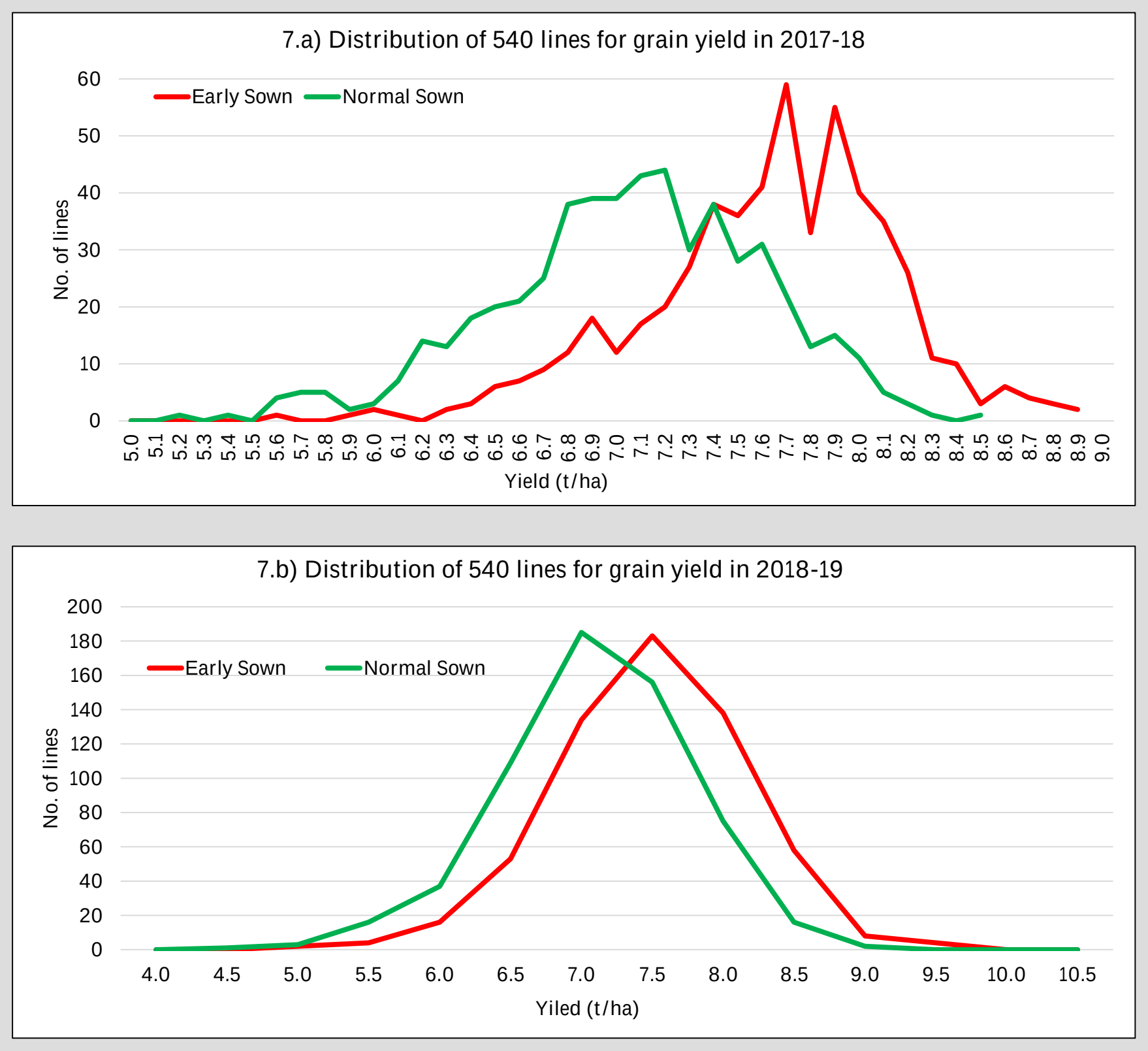


Figure 7: ~1 t/ha yield gain in early sown

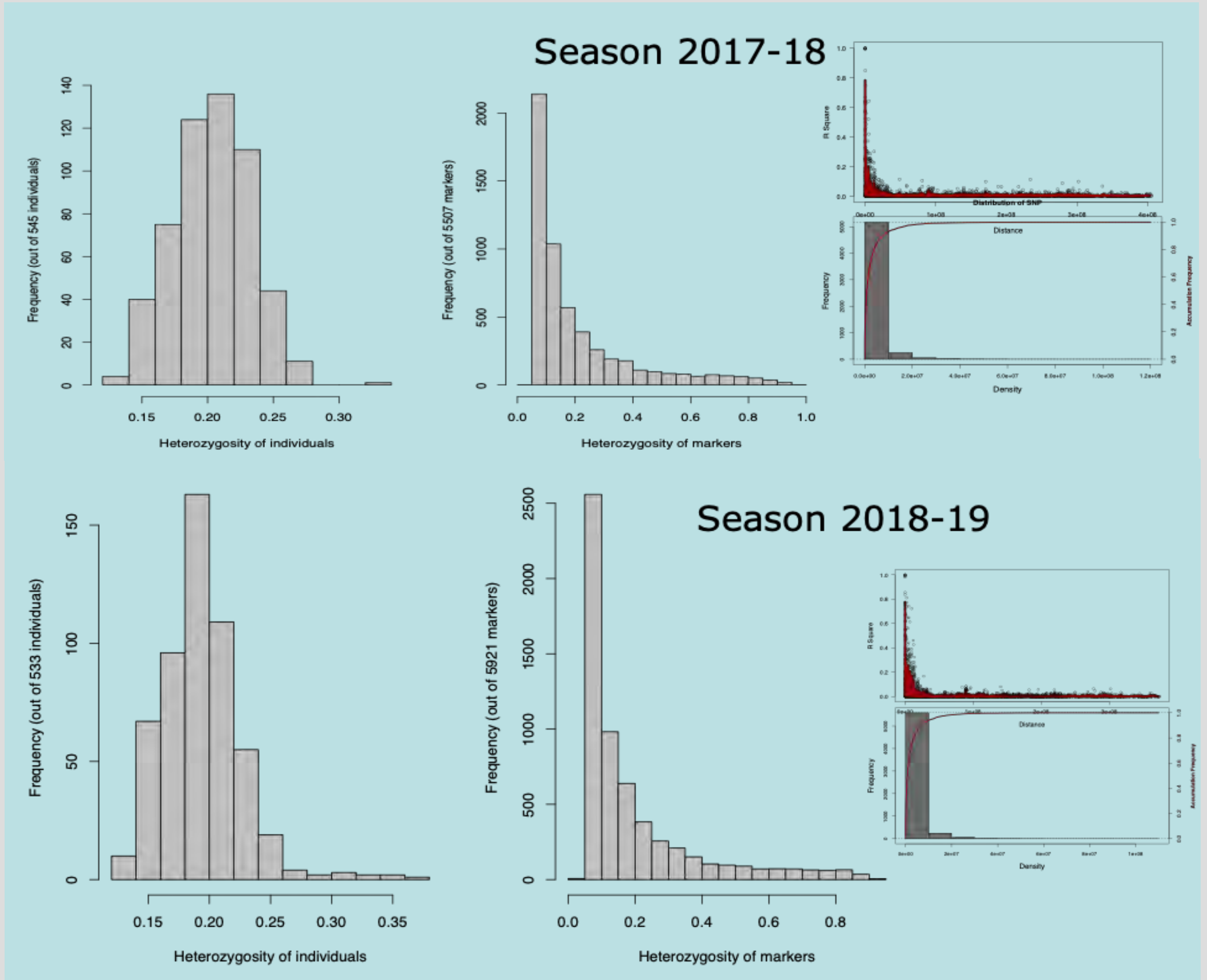


Figure 8 : Quality of GBS data used in the study for GWAS

Table 1: Models used for Genome wide association studies in GAPIT3 package

SL	Models	Full name	Reference
1	GLM	General Linear Model	McCullagh & Nelder FRS, 1989
2	MLM	Mixed Linear Model	Yu et. Al., 2006
3	CMLM	Compressed Mixed Linear Model	Zhang et. Al., 2010
4	ECMLM	Enriched CMLM	Li *et al*. 2014
5	MLMM	Multiple Loci Mixed Linear Model	Segura *et al*. 2012
6	SUPER	Settlement of MLM Under Progressively Exclusive Relationship	Wang *et al*. 2014
7	FarmCPU	Fixed and random model Circulating Probability Unification	Liu *et. al*. 2016
8	Blink	Bayesian-information and Linkage-disequilibrium Iteratively Nested Keyway	Huang *et al.* 2019

Table 2: Identified SNP Markers by GWAS (at least common in two models)

SL	Trait	Significant Markers			
		Early		Timely	
		2017-18	2018-19	2017-18	2018-19
1	Grain Yield	S7B_641768035			
2	Booting Days	S5B_595131483; S5B_553933522	S5D_548099351; S4B_655266936; S7B_7799230	S7B_741871808	-
3	Heading Days	S5B_595131483	-	S2B_58748723; S2B_50583313; S2B_51077637	S6A_23717783; S2B_797272956; S2B_728197427
4	Maturity Days	-	S4B_659528084; S7A_730099718		S2A_768930701; S7D_60051411
5	Booting to Heading days	S2B_50583313	-	S2B_50583313; S2B_58748723; S2B_49846205; S2B_49523577; S2B_51077637; S2B_49523499;	-
6	Heading to Maturity Days	S5B_553933522	-	-	S2B_797272956
7	Plant Height (cm)	S2B_797272956; S2B_797278603	S7D_514567222	-	S2B_797272956; S2B_797278603; S2D_649880368
8	Spike length (cm)		S7B_594026635	S3D_353373144	
9	Leaf Length (cm)	S5B_530798068			
10	Leaf Width (cm)	-	S2A_238637321; S2B_797272956		S2B_797278603; S2B_797272956; S6B_720492453
11	1000 grain weight	S2D_617047472	S4B_619736929		S4B_619736929
12	Senescence Rate	S5B_595131483	-	S2B_58748723	S3B_5543559; S5B_668750886
13	CT Increasing Rate	-	S2D_8787004; S7A_563559305	S2B_50583313	-

CONCLUSIONS

High trait variation was observed in early planting. Although less time required for booting and heading but longer maturity was observed which reviled that early planting poses good impact on yield through interaction with phenological traits. Longer grain filling period, delay senescence and less canopy temperature increasing rate supported higher grain yield in early planting. GWAS revealed several SNPs for early establishment. The study provided an insight for a scope to enhance gain higher grain yield by early planting.

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