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## INTRODUCTION

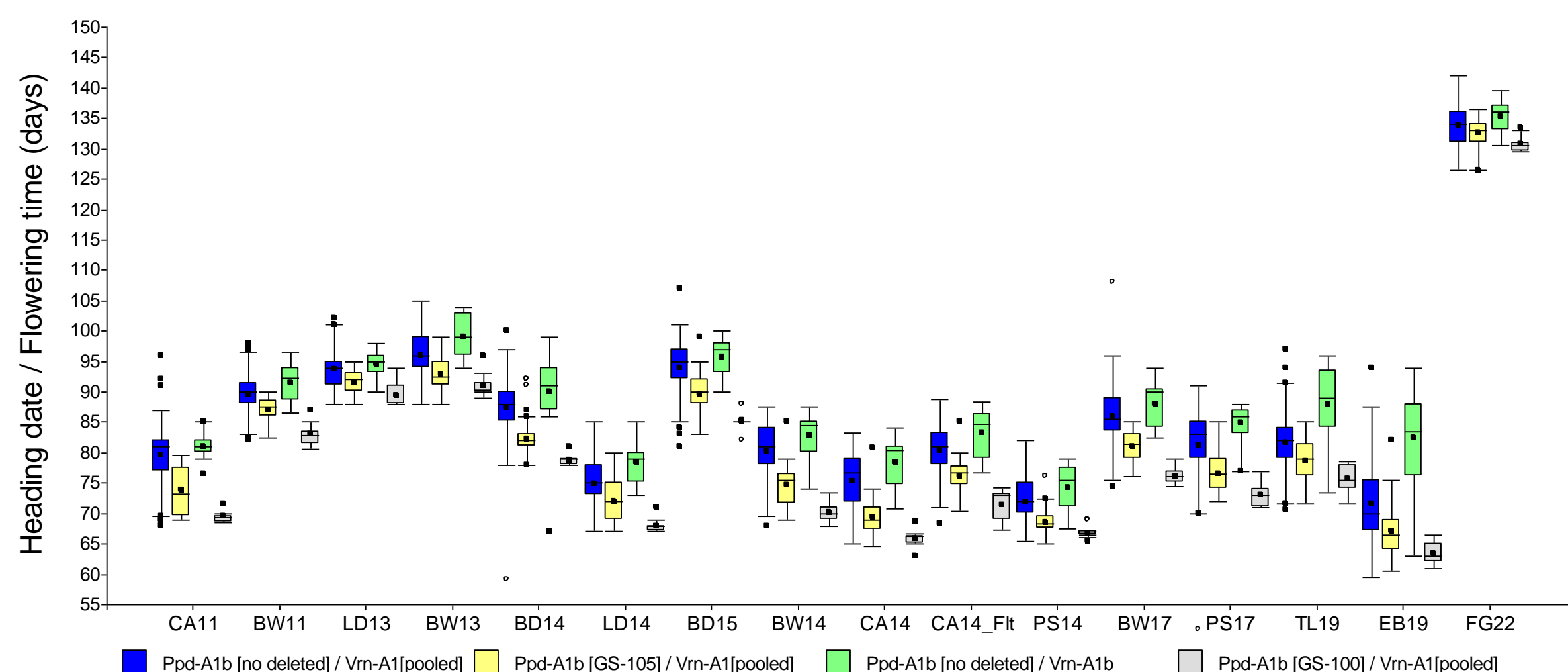
Grain yield is affected by developmental genes involved in photoperiod sensitivity (*Ppd*), vernalization (*Vrn*) and plant height (*Rht*). However, additional unknown genes are also affecting wheat yield and morfo-phenological traits. The objective of this study was to contribute of deciphering the genetic bases of grain yield and morfo-phenological traits in durum wheat.

## METHODS AND MATERIALS

A collection including a total of 197 durum wheat genotypes was evaluated under field conditions between 2011 and 2022 in Argentina, Mexico and Italy, including replicated (10) and non-replicated trials (7), for yield (7), plant height (8), peduncle length (5), heading date (14) and flowering time (1). The alleles at *Rht-B1*, *Ppd-A1* and *Vrn-A1* genes were evaluated using SNP (KASP) and STS markers. Analyses were performed in INFOSTAT (Di Renzo et al. 2010) and TASSEL 5 (Bradbury et al. 2007)

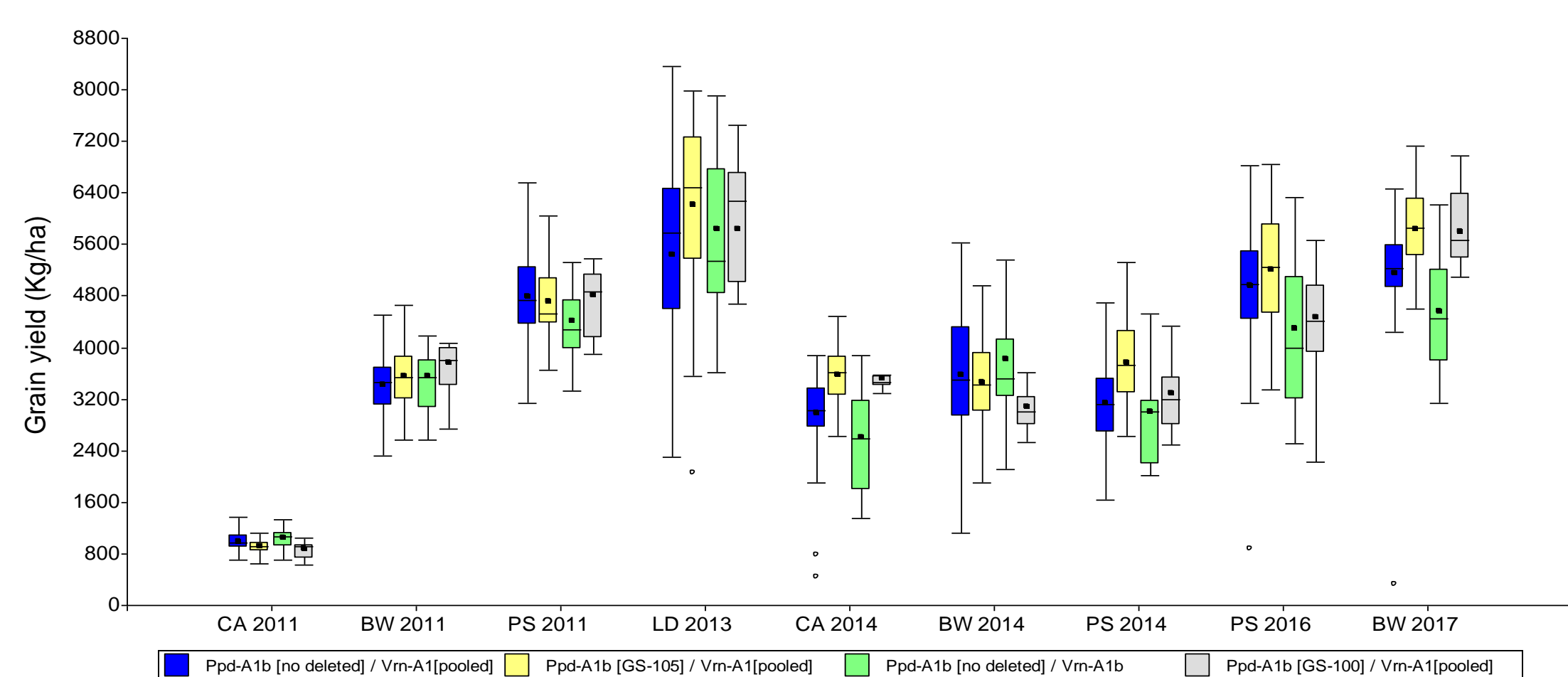
## RESULTS

The effect of the *Ppd-A1/Vrn-A1* alleles combination on the heading date was classified from the shorter to the longer in number of days as *Ppd-A1a* (GS-100) < *Ppd-A1a* (GS-105) < *Ppd-A1b/Vrn-A1c/a* < *Ppd-A1b/Vrn-A1b* across 15 trials.



**Fig. 1** Box plot of heading date and flowering time considering the *Ppd-A1/Vrn-A1* alleles combination in 15 environments using three population sizes (2011[N=133], 2013-2017 [N=170], 2019-2022[N=197]). CA=Cabildo; BW=Barrow; PS=Pierres; LD= La Dulce; BD= Bordenave; TL= Toluca (México); EB= El Batán (México); FG=Foggia (Italia). Pooled=*Vrn-A1c* / *Vrn-A1a(1)* / *vrn-A1(1)*

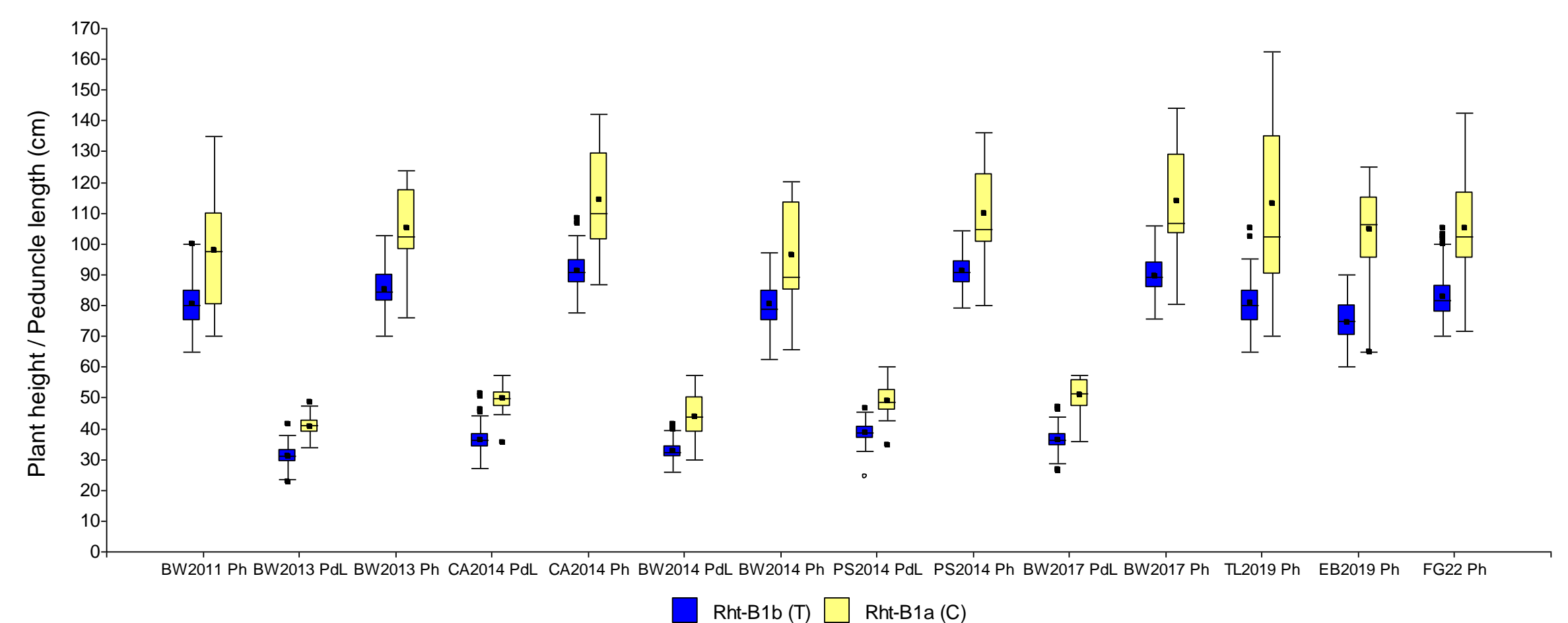
The *Vrn-A1b* spring allele reported by Yan et al. (2004) was detected in 12.7% of entries, 2-5 fold higher frequency than in other panels. Our study demonstrated the effect of *Vrn-A1b* allele to delay the heading date in durum wheat (Figure 1). This allele was detected in older (tall) and modern (semi-dwarfs) genotypes including the landraces Taganrog and Cappelli, the putative donors of this allele in the modern germplasm in our collection.



**Fig. 2** Box plot of mean grain yield considering the *Ppd-A1/Vrn-A1* alleles combination in seven replicated trials and two un-replicated trials (LD2013, PS2016) (2011[N=133], 2013-2017 [N=170]).

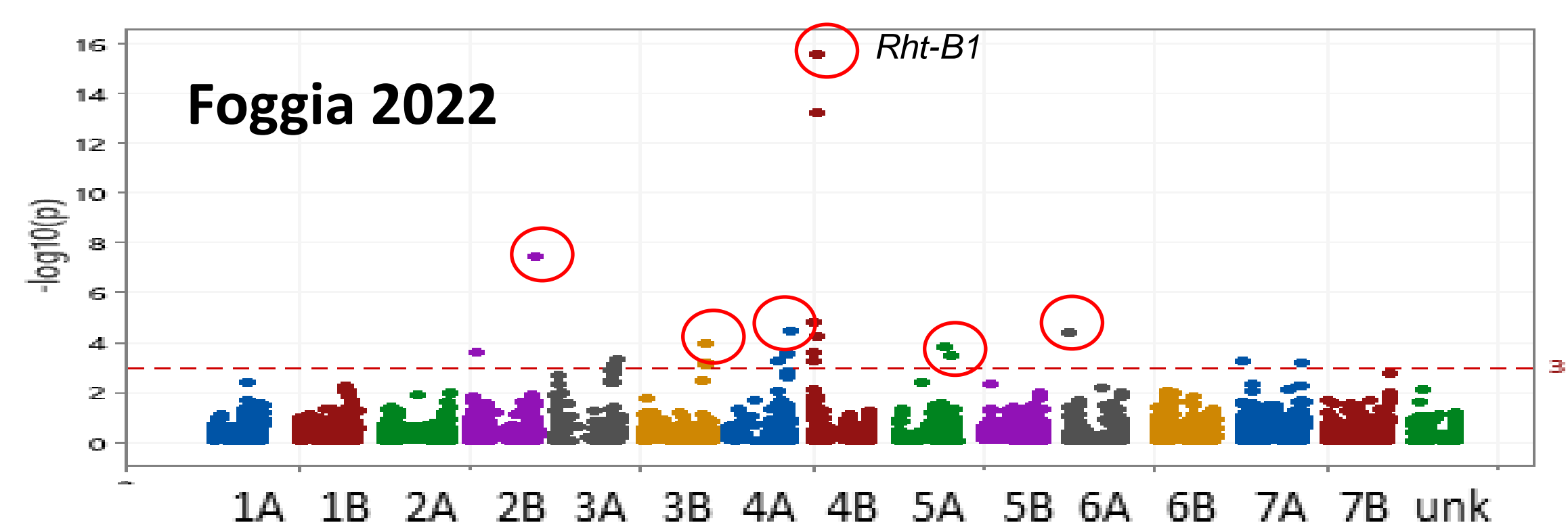
The GS-105 allele at *Ppd-A1* resulted in increased grain yield in five environments, followed by GS-100 allele in three trials. Only nine genotypes carried the GS-100 allele which confer photoperiod insensitive in this durum wheat collection.

While genotypes carrying *Vrn-A1b* received a grain yield penalty, with the exception of two environment CA 2011 (had a severe drought) and BW 2014 (had a flood period) in which the allele maybe contributed to escape the stress condition.



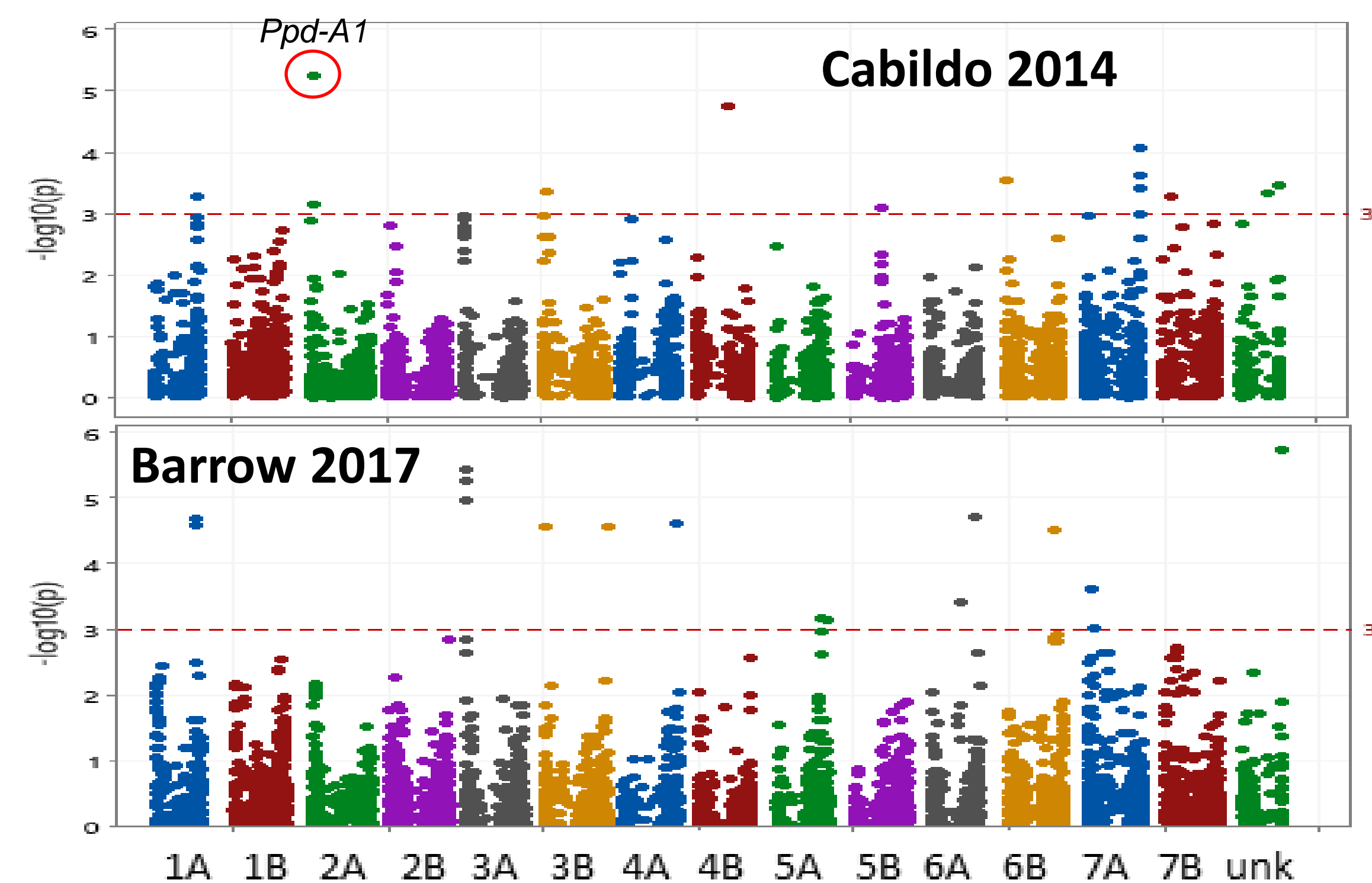
**Fig. 3** Box plot of mean plant height and peduncle length considering the *Rht-B1* alleles in eight replicated trials and one un-replicated trial (BW 2011) (2011[N=133], 2013-2017 [N=170], 2019-2022 [N=197]).

The *Rht-B1* gene marker and three linked SNPs (AX-94438527, AX-94685504, AX-94685096) showed a strong effect on plant height and peduncle length in all trials, together with loci detected by marker-trait associations (MTA) in 11 (6AL, 4AL, 7BL), 10 (2B, 3BL), 7 (5BL, 7AL), 6 (3AL) trait-environment combinations (Figure 3).



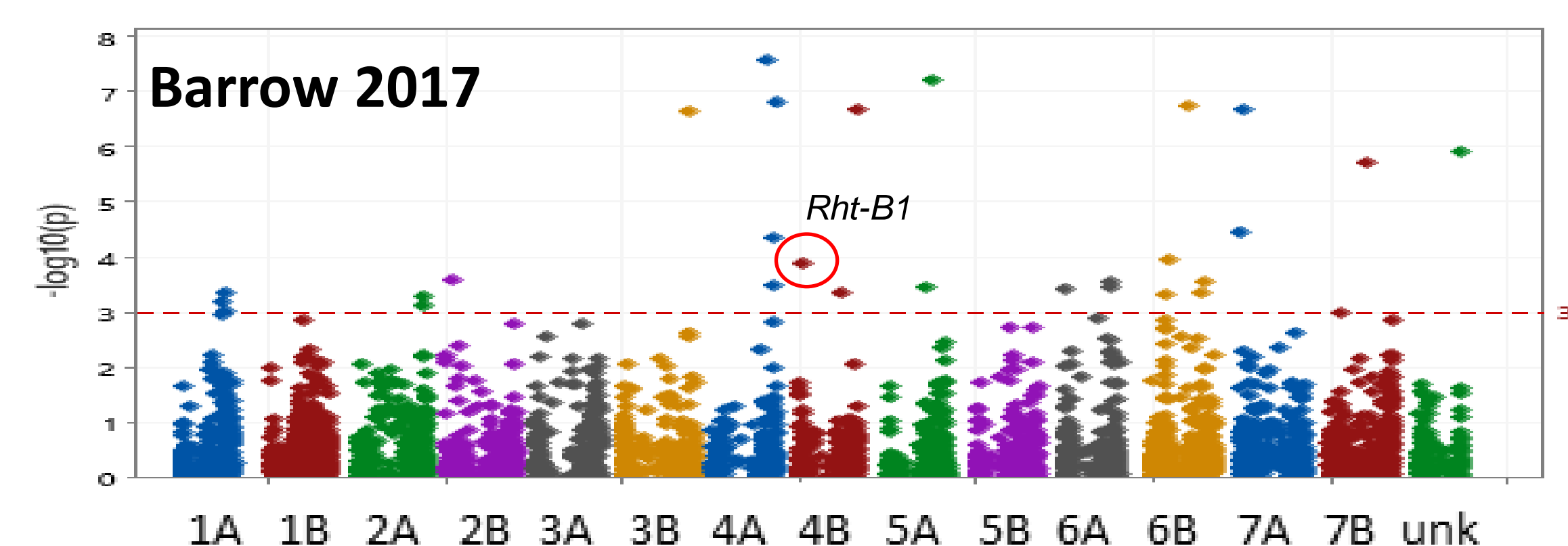
**Fig. 4** Marker-trait association analysis for plant height in one of eight evaluated environments.

The MTA for heading date were mainly significantly detected in 8 (2A), 6 (7AL), 5 (3AS), 5(3BS), 5 (7AS), 4 (2BS), 4 (4BL), 3 (4AL), 3 (6AL) environments. A second SNP on the *Ppd-A1* sequence (AX-94458060) was significant in eight environments.



**Fig. 5** Marker-trait association analysis for heading date in two out of 15 environments.

For grain yield, MTA were detected on 3BL, 4AL, 4BS, 4BL, 5AL, 6BL, 7AS and 7BL in three environments. The SNPs AX-94718060 (6AL) and AX-95146558 (7AL) affecting plant height showed a significant effect on grain yield in most of environments.



**Fig. 6** Marker-trait association analysis for grain yield in one of seven replicated environments.

## CONCLUSION

The finding of new loci for morfo-phenological traits could allow the fine tuning of these traits and the grain yield improvement.