

腺嘌呤核苷三磷酸 (F1-ATPase) 緩解育種階段高溫脅迫所導致之損害

F1-ATPase relieves the damage caused by a high temperature stress during seed development

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在種子發育過程中，高溫脅迫會導致帶聖白胚乳的籽粒品質下降，這是由於在種子發育過程中，三磷酸腺苷供應不足及能量短缺而導致的澱粉合成不足造成的。在這種情況下，由於參與腺嘌呤核苷三磷酸合成酵素之基因的表達明顯降低，從而大量減少了影響籽粒品質的腺嘌呤核苷三磷酸合成酵素的數量。我們創造了在未成熟的種子中能夠過度表達的腺嘌呤核苷三磷酸合成酵素之轉化株。其增強了耐高溫脅迫的能力並生產出在正常條件下才能發育的正常形狀的籽粒。這表明了獲取應對高溫損害之耐受性的可能性。

糧食產量對諸如過高或過低的溫度、水滯以及乾旱等非生物脅迫非常敏感。未來全球變暖會在水稻種子發育的籽粒灌漿階段帶來高溫壓力，這將降低農作物之產量與品質。在水稻領域，種子發育過程中的高溫環境將使稻籽之特性產生很多變化，諸如白聖狀結構、乳白色外觀，並使穀粒重量降低。這些變化的產生是由於澱粉顆粒的增長不足而在胚乳中形成了大量空間。如果水稻種子在高溫條件下發育，多基因的表達，諸如在胚乳中的澱粉合成的反應，就會被壓制；這將減少直鏈澱粉含量以及支鏈澱粉的結構異常。因此，由於蔗糖的匯入 / 降解及澱粉合成的受體下調、和 / 或澱粉降解的受體上調、以及因細胞色素呼吸鏈之抑制而產生的低效三磷酸腺苷，澱粉沉積可能會受到損害。



Table 1. Proportion of defective grain produced in normal and high temperature conditions by eight rice cultivars.

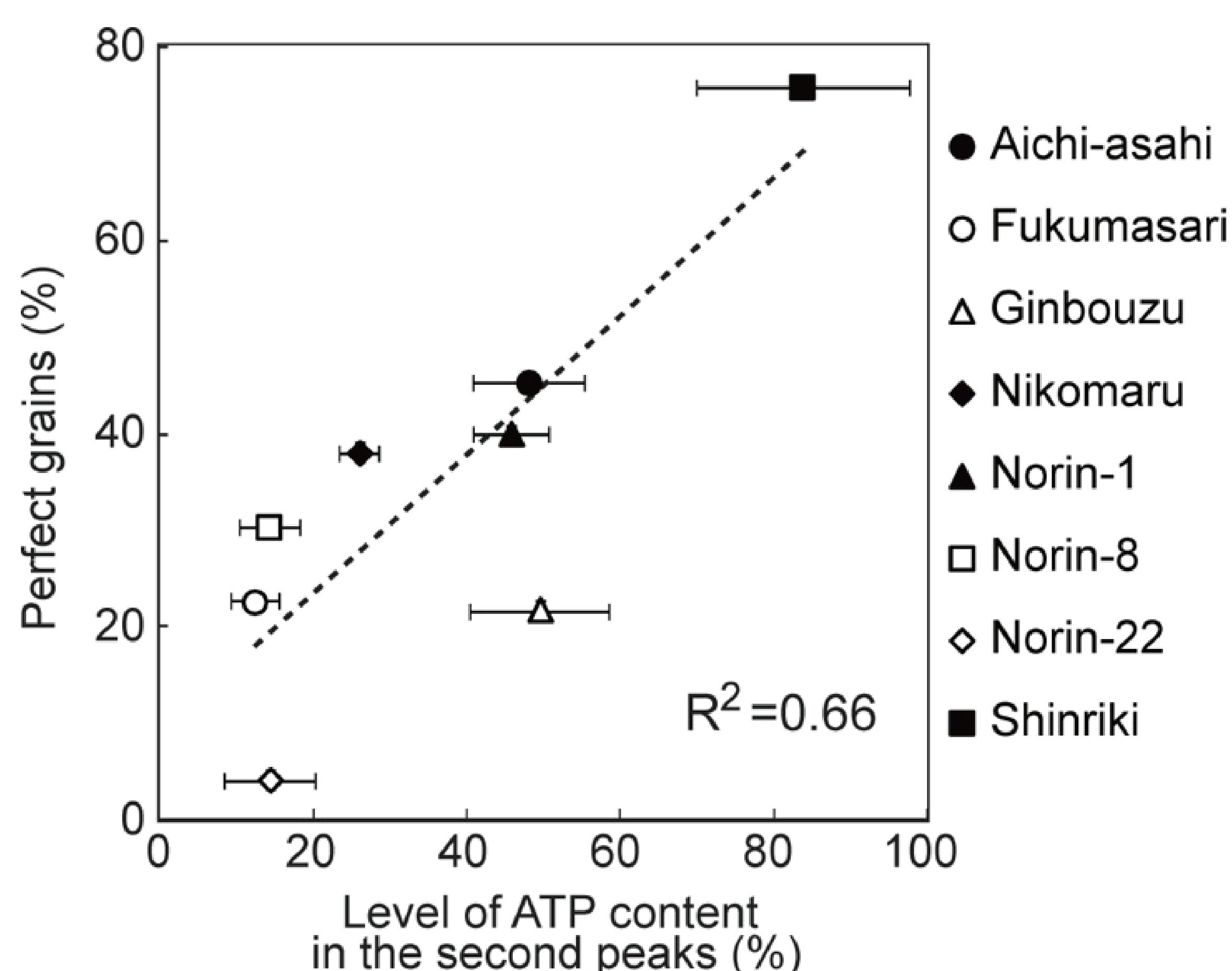
Grain feature	Shinriki		Aichi-asahi		Norin-1		Nikomaru	
	Normal	High	Normal	High	Normal	High	Normal	High
Perfect grain	96.0	76.0	96.0	45.5	96.2	40.0	91.3	38.1
Basal white	0	12.0	4.0	0	0	28.0	0	28.6
White back	0	12.0	0	40.9	0	32.0	4.3	14.3
White belly	4.0	4.0	0	31.8	3.8	16.0	0	4.8
White core	0	8.0	0	13.6	0	12.0	4.3	9.5
Milky white	0	0	0	0	0	0	0	14.3

Grain feature	Norin-8		Fukumasari		Ginbozu		Norin-22	
	Normal	High	Normal	High	Normal	High	Normal	High
Perfect grain	95.8	30.4	82.6	22.7	100	21.7	92.3	4.2
Basal white	0	17.4	13.0	36.4	0	0	7.7	25.0
White back	4.2	34.8	0	50.0	0	30.4	0	50.0
White belly	0	4.3	0	9.1	0	4.3	0	8.3
White core	0	26.1	4.3	13.6	0	26.1	0	41.7
Milky white	0	0	0	4.5	0	30.4	0	25.0

The proportion of grains with defective characteristics is indicated. For this analysis we used randomly selected 25 grains that were harvested from three individual pots of each line. Values are expressed as a percentage of the total grain. The sum of the values was not 100% because several grains exhibited two or more characteristics. "Normal" and "High" indicate the results for grains grown in normal and high temperature conditions, respectively.

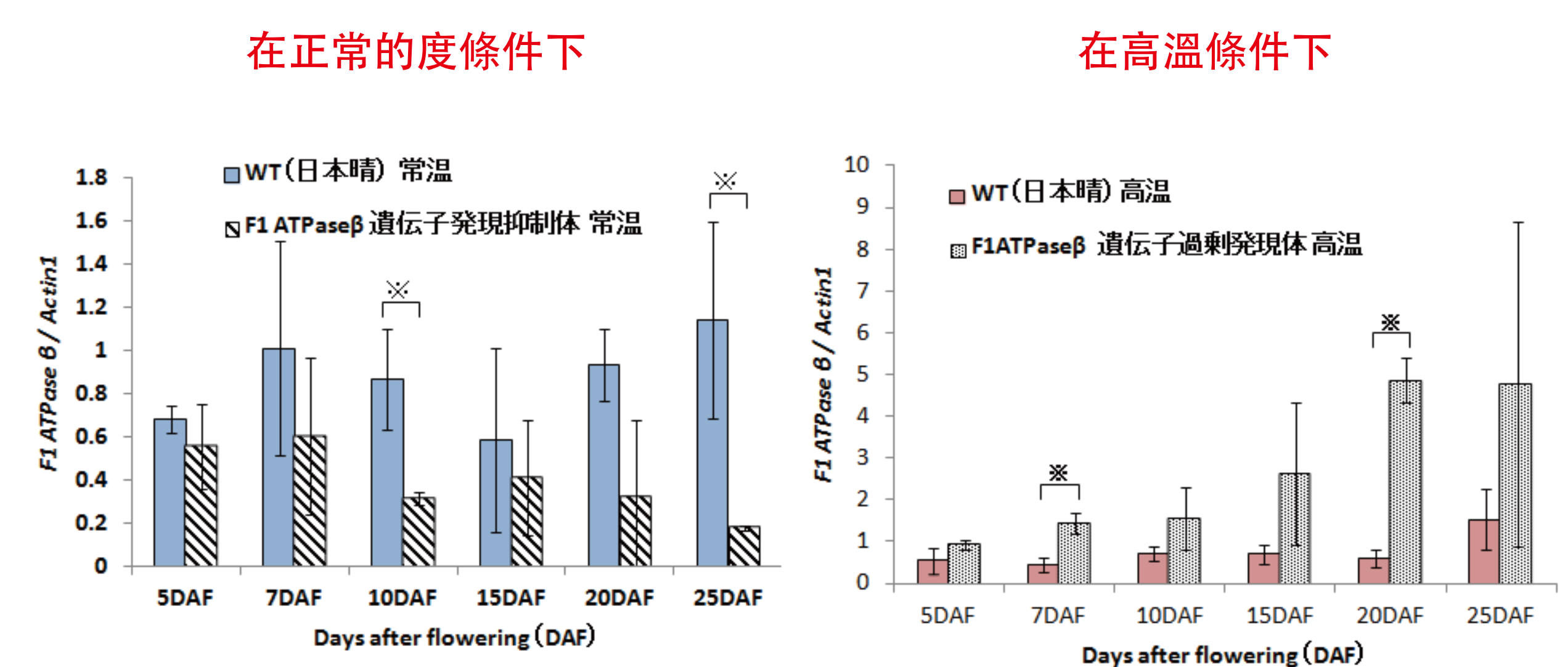
We evaluated the high temperature stress tolerance of eight representative rice cultivars. All eight cultivars produced normal-shaped, good quality grains when grown in normal conditions. By contrast, when grown under high temperature conditions, the rice grains of many of these cultivars exhibited major defective characteristics such as having basal white and white back grains, a chalky area on the dorsal and proximal sides, or white core endosperm.

種子發育過程中，良好穀粒的比率和三磷酸腺苷含量的相關性分析

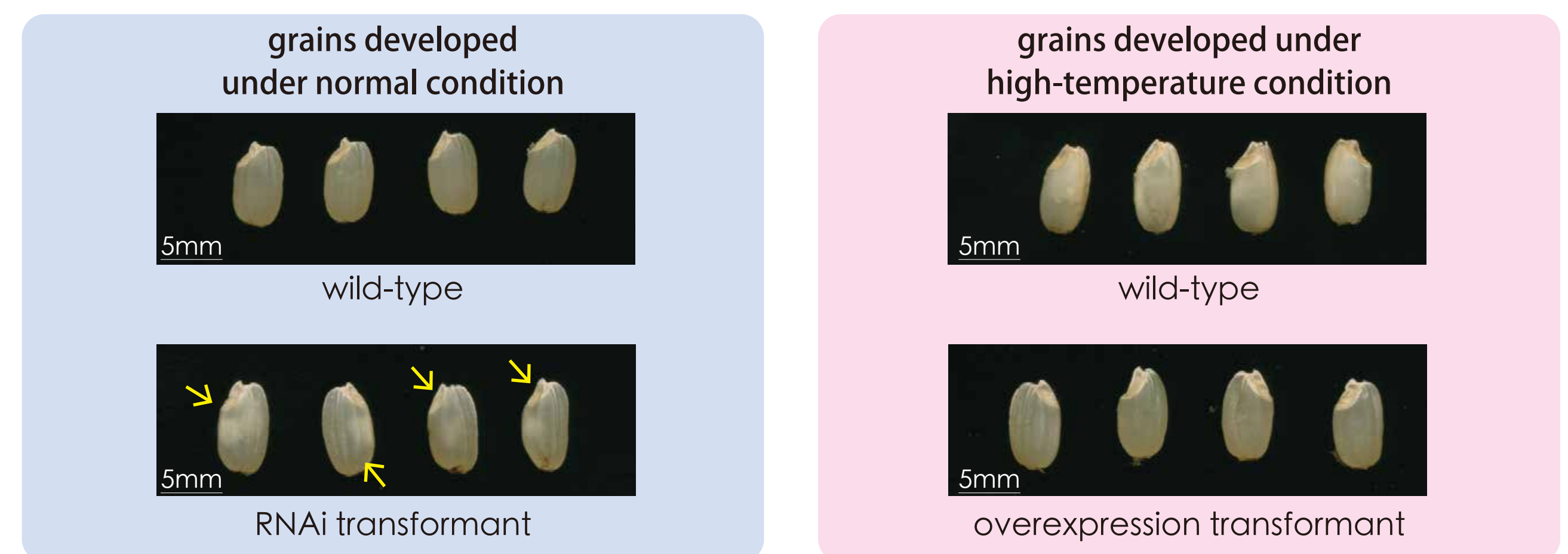


We detected the correlation between the proportion of the perfect grain and the ratio of the level of the ATP contents at the second peaks in the high temperature conditions to those in the normal conditions (Figure 4). This suggests that reduction of ATP content corresponding to the second peak causes insufficient grain filling in the high temperature conditions.

包含核糖核酸幹擾的轉化株表型與三磷酸腺苷酶 b 型基因的過度表達

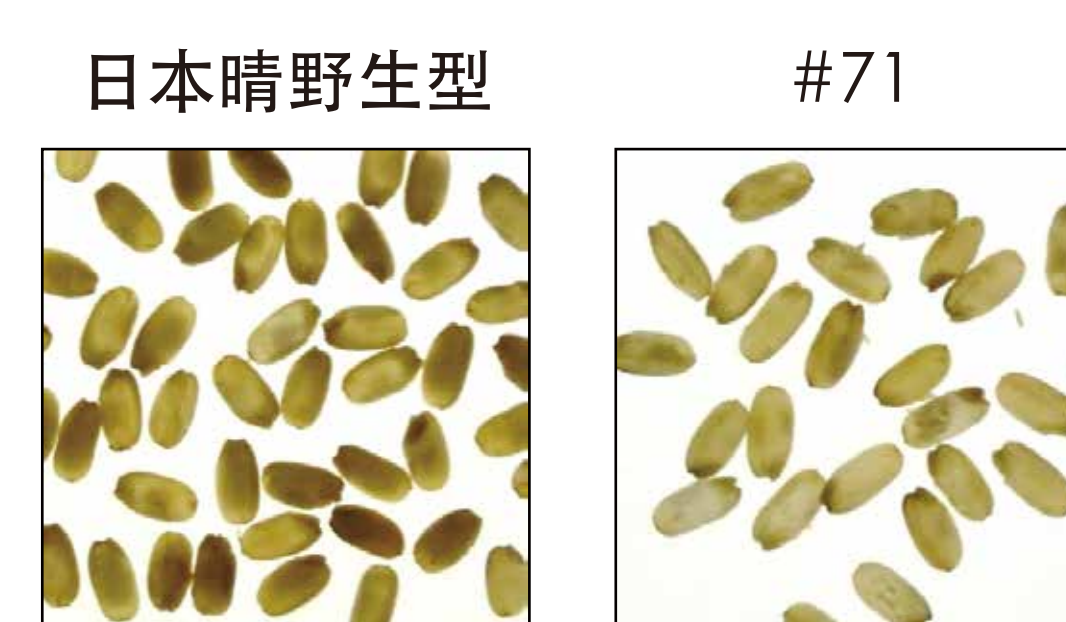
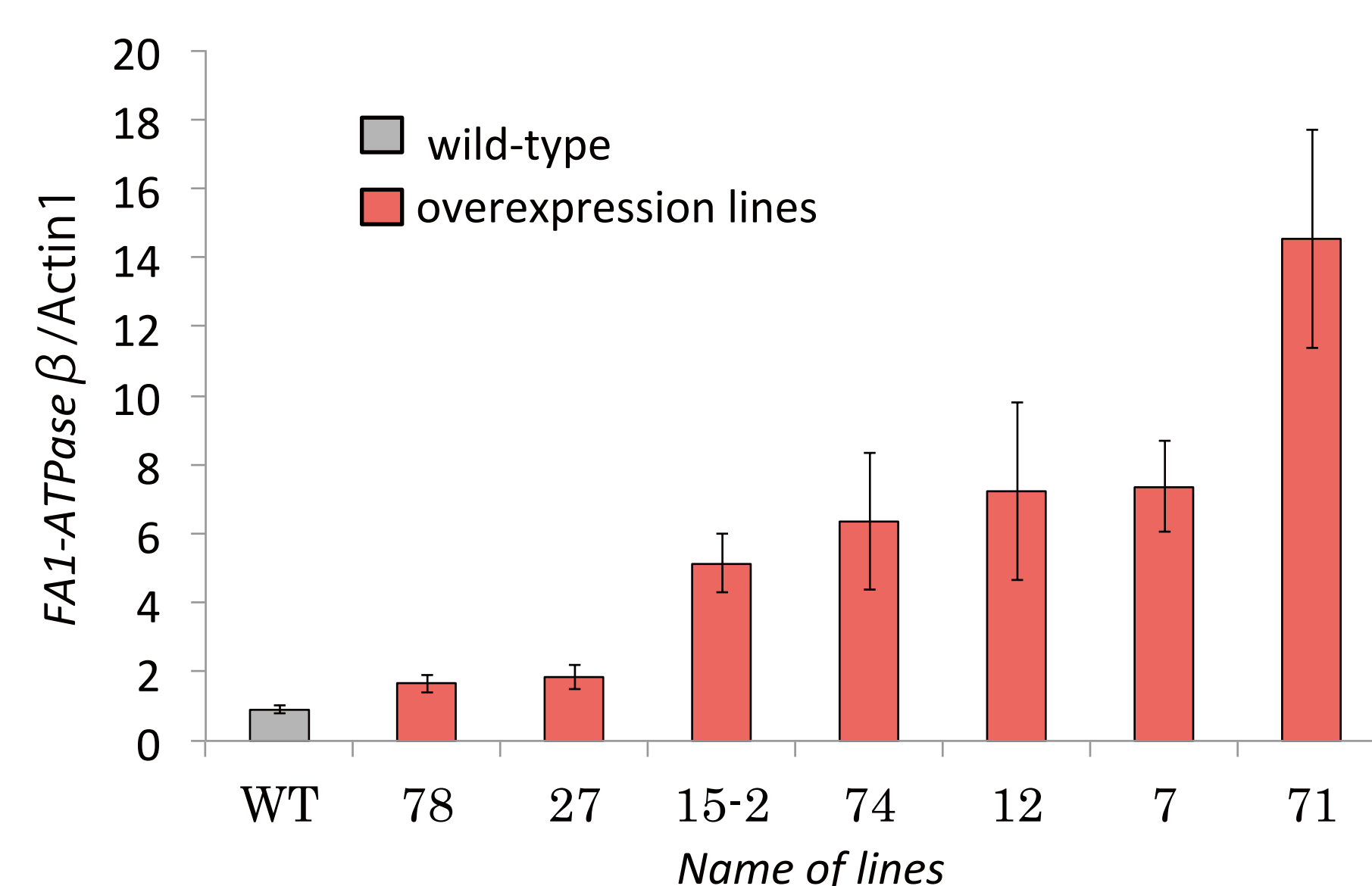


轉化株中三磷酸腺苷酶 b 型基因的表達



We created rice transformants in which the ATPase b gene was repressed by RNAi and overexpressed by the developing seed specific promoter, respectively. The RNAi transformants produced grains with reduced quality such as white core seeds even when they were developed under the normal temperature conditions. In contrast, the transformants in which the ATPase b gene was efficiently expressed in immature seeds showed significant tolerance to the damage by the high-temperature stress during seed development.

三磷酸腺苷酶 b 型的過度表達因高溫脅迫導致損害恢復



We found significant correlation between strength of tolerance to the high-temperature stress and the expression levels of ATPase b gene in the transformants. This indicated that high-level expression of the ATPase b can rescue the damage by the high-temperature stresses during seed development. Our results suggest that potentials of ATP supply in developing seeds are very important to acquire the tolerance to the high-temperature damage. Strength of ATPase activity or high-level expression of the ATPase gene was available for the usable marker for breeding of the new rice lines.

應用領域 Applications

一個具有高溫脅迫損害耐受性的水稻植物品種的分子育種。
作為對耐受植物選擇之分子標記的腺嘌呤核苷三磷酸合成酵素之活性。
Molecular breeding of a Rice plant tolerant to high-temperature stress damage.
ATPase activity as a molecular marker for selection of a tolerant plant.

優勢 Advantages

可應對全球變暖帶來之環境改變的一個新品種之分子育種。
Molecular-based breeding of a new cultivar that adapt to an environmental alteration by the global warming.