Chapter 7

General discussion

'Chiang Mai Pink' (*Curcuma alismatifolia* Gagnep.) a member of tropical and sub tropical geophytes, quantitatively required long day length and high night temperature for the normal shoot growth and flowering during regular season (RS) cropping in rainy seasons. The results presented here revealed that production season affected on some physiological aspects and also induced the changes in some endogenous hormones, other biochemical substances and photosynthetic rate, while the distinct environmental factor, as short day length (SDL) and low night temperature (LNT), also imposed their various influences on those physiological and biochemical aspects.

Many reports had been promulgated the influence of planting season on the levels of endogenous hormones and relationship to their growth, such as in douglas-fir, a woody tree (Doumass and Zaerr, 1988), apple (Sivaci and Yalcin, 2008; Tromp and Ovaa, 1990), valencia orange (Ribeiro *et al.*, 2009) and willow (Alvim *et al.*, 1976). In the first experiment, the off-season (OS) cropping brought about the dramatic increase in ABA levels in leaves, old rhizomes and old storage roots (Fig.

3.4) and the slight increase in *t*-ZR levels in leaves, old rhizomes, old storage roots, inflorescence and new rhizomes (Fig. 3.5), but caused the slight decrease in the levels of diffusible IAA in leaves at pre dormancy stage (Fig. 3.6).

Considering the accumulation of ABA, which was widely accepted to be a physiological response to adverse conditions; i.e. drought, cold, heat or salinity (Zeevaart, 1999) by raising its levels and depressing the growth process (Kondrat' Eva *et al*., 2009). The similar response might be .explained the effects of low temperature induced the increased ABA levels in this finding under the OS condition which were reflected in the negative correlations among plant heights, leaves fresh weight and endogenous ABA levels in leaves of *Curcuma* plants (Table 3.5). In addition, ABA accumulation and low temperature in OS resulted in increased rhizomes yields, it could be considered to be similar to their influences that related to bulb formation, thickening and dry matter accumulation and sink-source relationship in *Curcuma* (see more detailed, discussion in **chapter 3**).

The high accumulation of *t*-ZR in various organs which promoted the rhizome yields might indicate its possible role in controlling the meristematic cell differentiation of root (Dello Ioio *et al*., 2007; Kyozuka, 2007), creating a sink and regulating the expression of gene implicated in assimilate partitioning (Roitsch and Ehneß, 2000). This hypothesise was supported by the positive correlation between new rhizome yield and the levels of *t*-ZR in old rhizomes of OS plant (Table. 3.5).

Reduction in the levels of IAA in OS plants could suggest its contributable relation with their inferior shoot growth (Fig. 3.6), since auxin had been reported to implicate in tuber physiology and would not be mainly responsible for inhibition of sprouting in potatoes (Sorce *et al.*, 2009).

Focusing on the fluctuation of endogenous hormone which has been shown briefly (only at flowering stage) to confirm the possible role of day length and temperature in hormonal changes in Table 7.1 (see more detail in **chapter 4** and **chapter 5**). Short day length (SDL) 13 h strongly affected on endogenous hormone rather than low night temperature (LNT) 30/18^{0}C. SDL-induced ABA in the aboveground organs and *t*-ZR in underground organs, while the LNT increased *t*-ZR only in underground organs. These findings might be represented as the schematic endogenous hormone variation dynamic model in *C. alismatifolia* (Fig. 7.1 to 7.3). The model in fig. 7.1 suggested some conceptual ideas in both planting seasons that old storage roots might be functioned as storing reserves for ABA, while leaves and old storage roots being played the role as temporary storage tanks for *t*-ZR in growth cycle. Both proposed models (Fig. 7.2 and 7.3) also supported the first idea that the changes in endogenous hormone by environmental factor in different seasonal cropping were at least the SDL and LNT. However, the changes of promoting endogenous hormone, as GAs, did not investigate in this study. It was assumed that GAs was the important hormone, which partly played the role in response to distinct environmental factors in this plant, since the application of gibberellin synthesis inhibitor, as paclobutrazol and flurprimidol, had been reported to reduce plant height and flower stalk length in *C. alismatifolia* and *C. roscoena* (Thohirah *et al.*, 2005). Thus, the investigation of endogenous GAs during growth cycle of *Curcuma* plant should be explored in further study.

Table 7.1 Summary of endogenous hormonal changes (ABA, *t*-ZR and IAA) in various parts of *C. alismatifolia* at flowering stages (12 WAP)

Hormones	**ABA**						***t*-ZR**						**IAA**	
Experiment	**Exp 1**		**Exp 2**		**Exp 3**		**Exp 1**		**Exp 2**		**Exp 3**		**Exp 1**	
Treatment	**RS**	**OS**	**LDL**	**SDL**	**HNT**	**LNT**	**RS**	**OS**	**LDL**	**SDL**	**HNT**	**LNT**	**RS**	**OS**
Aboveground organs														
Leaves	↓	↑	↓	↑	↑↓	↑↓	↓	↑	↑↓	↑↓	↑↓	↑↓	↑↓	↑↓
Inflorescence	↑↓	↑↓	-	-	-	-	↓	↑	-	-	-	-	-	-
Underground organs														
Old rhizomes	↓	↑	↑↓	↑↓	↑↓	↑↓	↓	↑	↓	↑	↓	↑	-	-
Old storage roots	↓	↑	↑↓	↑↓	↑↓	↑↓	↑↓	↑↓	↓	↑	↓	↑	-	-
New rhizomes	↑↓	↑↓	-	-	-	-	↑	↓	-	-	-	-	-	-
New storage roots	↑	-	-	-	-	-	-	-	-	-	-	-	-	-

RS: regular season, OS: off-season, LDL: long day length, SDL: short day length, HNT: high night temperature and LNT: low night temperature

↑ = higher, ↓ = lower, ↑↓ = inconsistent, and - = not proof

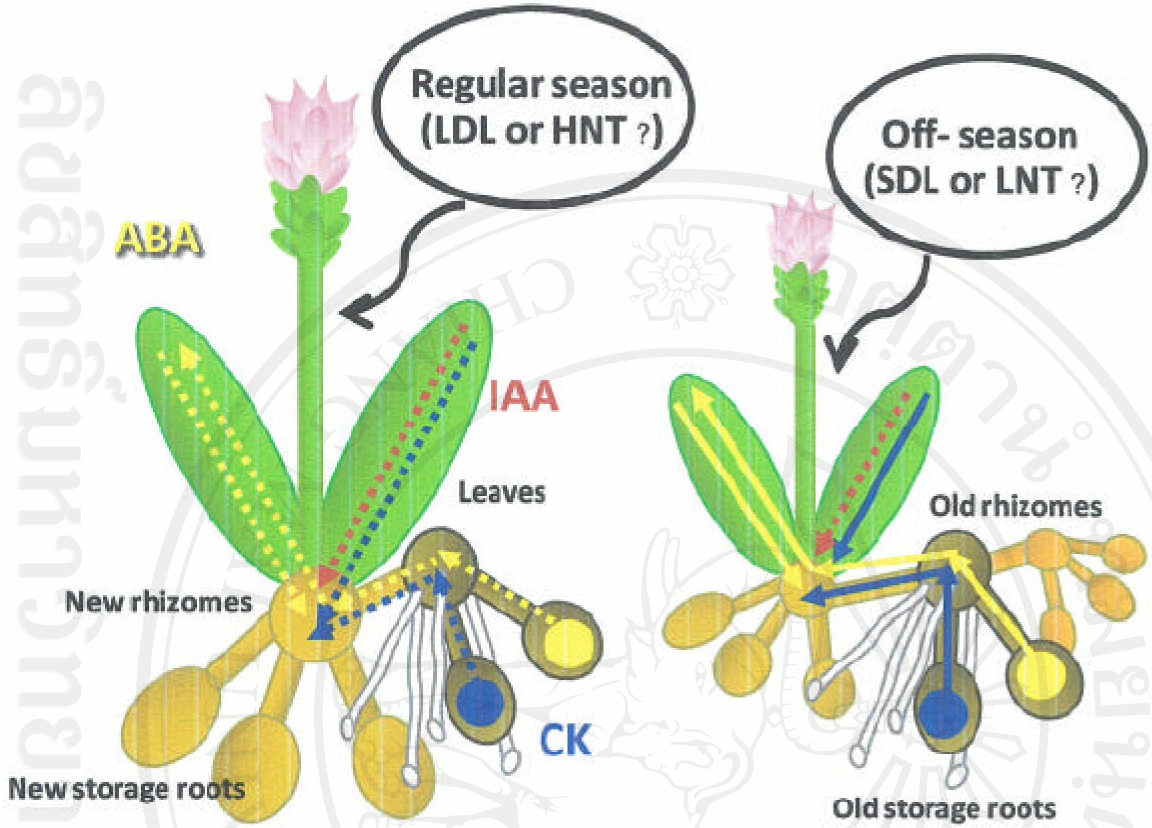

Fig. 7.1 Schematic model of endogenous hormonal changes (ABA (yellow arrows), CK as *t*-ZR (blue arrows) and diffusible IAA (red arrows)) in *C. alismatifolia* grown under regular season (RS) cropping and off-season (OS) cropping at flowering stage (12 WAP). Leaves and old storage roots suggested serving as temporary ABA tank, while the old storage roots might play a role in temporary *t*-ZR tank. Solid arrows indicated the increased concentration and dotted arrows indicated the decreased concentration.

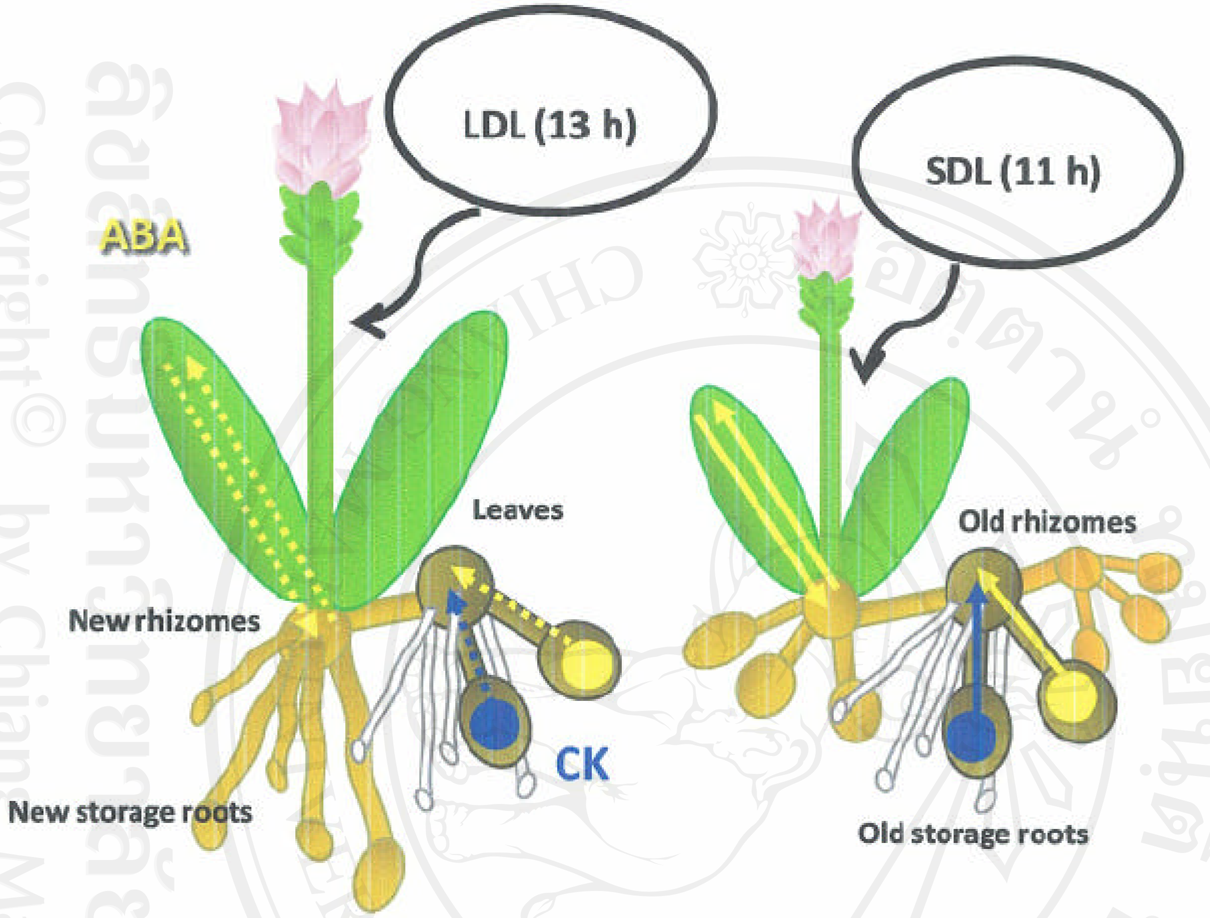

Figure 7.2 Schematic model of endogenous hormonal changes (ABA (yellow arrows) and CK as *t*-ZR (blue arrows)) in *C. alismatifolia* grown under long day length (LDL) 13 h and short day length (SDL) 11 h at flowering stage (12 WAP). Solid arrows indicated the increased concentration and dotted arrows indicated the decreased concentration.

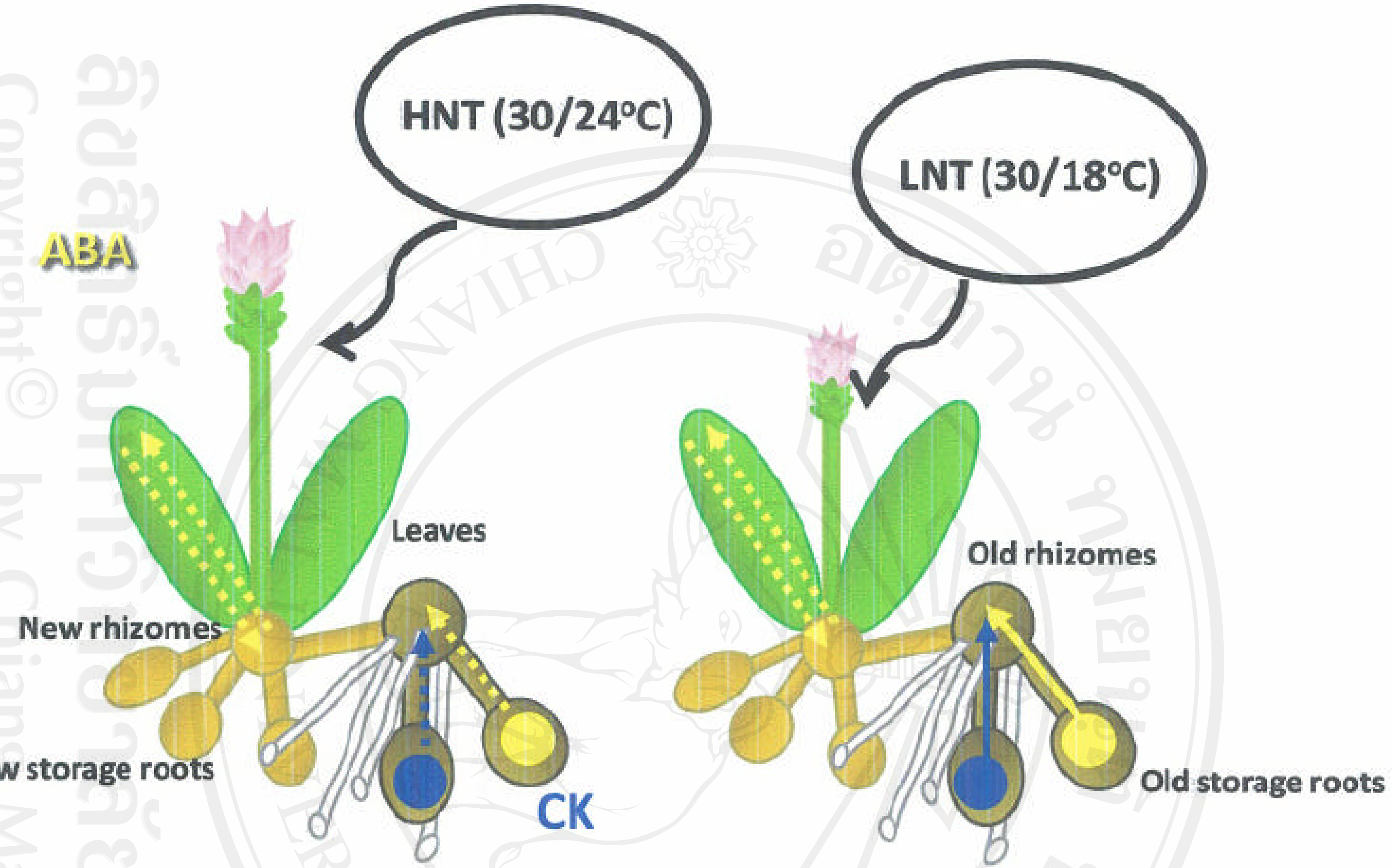

Figure 7.3 Schematic model of endogenous hormonal changes (ABA (yellow arrows) and CK as *t*-ZR (blue arrows)) in *C. alismatifolia* plant grown under high night temperature (HNT) 30/24^{0}C and low night temperature (LNT) 30/18^{0}C at flowering stage (12 WAP). Solid arrows indicated the increased concentration and dotted arrows indicated the decreased concentration.

The changes in free sugars contents were briefly shown in Table 7.2, in which OS condition seemed to increase the monosaccharides (fructose and glucose) in whole plant. Inconsistent with SDL and LNT conditions, which seemed to reduce the total free sugars content (fructose, glucose and sucrose), especially in the underground organs. However, it was revealed that sucrose was the dominant soluble carbohydrate in storage organs. Generally, cold treatment caused a considerable increase in carbohydrate contents, as previously reported by Oquist *et al*. (1993), Galiba *et al*. (1997) and Benkeblia (2003). When bulbs were stored at low temperature, there was a net breakdown of starch and accumulation of sucrose from hydrolysis of starch (Shin *et al.*, 2002). Sucrose played a central role in growth and development of plants and the products of its degradation were important factors when internal sprouting can be initiated by utilizing accumulated free sugars (Benkeblia, 2003). The opposite finding of sugar content in both SDL and LNT might be explained by the insufficient assimilates translocation to promote their growth and development, causing a considerable depression in shoot growth and flower quality.

Seasonal cropping had also fluctuated the nutrient (N, P and K) contents (see more detail in **chapter 3**). SDL seemed to reduce N, P and K contents in all plant organs, except for that of P content in old storage roots. LNT also decreased the N and P contents in old rhizomes, and both N and K contents in leaves (see more detail in **chapter 4** and **5**). Such phenomena might be explained with the supporting report from Engel *et al*. (1992), that low temperature severely inhibited some nutrient uptake via the temperature effects on membrane permeability (Mozafar *et al*., 1993), although the nutrient composition was less affected by light regimes (Proebsting and Chaplin, 1981).

Table 7.2 Summary of free sugars contents (fructose, glucose, and sucrose) in various parts of *C. alismatifolia* at flowering stages (12 WAP)

Hormones	**Fructose**						**Glucose**						**Sucrose**					
Experiment	**Exp 1**		**Exp 2**		**Exp 3**		**Exp 1**		**Exp 2**		**Exp 3**		**Exp 1**		**Exp 2**		**Exp 3**	
Treatment	RS	OS	**LDL**	**SDL**	**HNT**	**LNT**	RS	OS	**LDL**	**SDL**	**HNT**	**LNT**	RS	OS	**LDL**	**SDL**	**HNT**	**LNT**
Aboveground organs																		
Leaves	↓	↑	↑↓	↑↓	↑	↓	↓	↑	↑↓	↑↓	↑	↓	↑	ND	ND	ND	ND	ND
Inflorescence	↑	↓	–	–	–	–	↑	↓	–	–	–	–	↑	ND	–	–	–	–
Underground organs																		
Old rhizomes	↓	↑	↑	↓	↑↓	↑↓	↓	↑	↑	↓	↑↓	↑↓	↑↓	↑↓	↑	↓	↑↓	↑↓
Old storage roots	↑↓	↑↓	↑	↓	↑	↓	↑↓	↑↓	↑	↓	↑	↓	↑	↓	↑	↓	↑↓	↑↓
New rhizomes	↑	↓	–	–	–	–	↑	↓	–	–	–	–	↑	↓	–	–	–	–
New storage roots	ND	↑	–	–	–	–	ND	↑	–	–	–	–	ND	↑	–	–	–	–
Whole plant	↓	↑	↑	↓	↑	↓	↓	↑	↑	↓	↑	↓	↓	↑	↑	↓	↑	↓

RS: regular season, OS: off-season, LDL: long day length, SDL: short day length, HNT: high night temperature and LNT: low night temperature

↑ = higher, ↓ = lower, ↑↓ = inconsistent, ND = not detected and - = not proof

Photoperiods had been known to affect the root formation and alter the partitioning of dry matter between root and tops, but no information was available as to the possible effects of photoperiods on the up take of mineral nutrients by the roots (Salisbury, 1981). Besides this finding, the controlling of the distinct environmental factors, at least, photoperiods and temperature or the application of suitable fertilizer, could be beneficial for promoting production of rhizomes yields.

OS condition also increased the total free amino acids concentration in most organs. Supporting this resulted by the SDL condition usually increased the total free amino acids concentration in all parts. Opposite result was found in the decreasing of total free amino acids concentrations during LNT condition. These changes might be consequently caused by the difference of protein hydrolysis, synthesis or conversion.

Base on the presented result above, the endogenous hormonal changes could also play important roles accompanying with other biochemical substances in the different growth and development and would be immense to find the optimum time for their effective utilization. However, some provided results in which suggested that photoperiods strongly affected on hormonal changes rather than the temperature prompted to prove a hypothesis that decreasing ABA concentration in plants by using night interruption as long day condition with gibberellins and fluridone applications might enhance the growth, flower quality and rhizomes yields. Surprisingly, the actually result revealed that light regimes by night interruption as long day condition did not affect any endogenous ABA concentration in overall, while this condition was found to strongly regulate *t*-ZR concentration only in old storage roots (see more detail in **chapter 6**). The antagonistic of ABA, GA_3 application certainly promoted the aboveground growth (plant height and flower quality), but did not affect the endogenous ABA concentration, the inhibitor of ABA, fluridone application failed to reduce ABA accumulation. These findings might be explained by the fact that ABA could be synthesized from other routes not accompanying pathway between ABA and carotenoids synthesis in which it was not activated site for fluridone metabolite or transported. Nevertheless, night interruption with GA_3 application could promote the aboveground organs (leaves and flower quality), but it slightly reduced underground yields (see more detail in the relationship of hormonal changes and physiological aspect in **chapter 6**).

Due to the practicable applying for commercial production of *Curcuma*, it should be suggested that the regular (RS) season cropping in rainy season (long day length, high night temperature, sufficient water supply etc.) brought about the complete vegetative growth with high quality of flower which was appreciated as cut flower. While the off-season (OS) cropping in cool dry winter (short day length, low night temperature, deficient water supply etc.) led to compact size of vegetative growth, but allowed to promote rhizomes yields with compact, numerous rhizomes and storage roots. Under this OS condition, night interruption with supplemental lighting could be necessary to enhance flower quality, but less productive in rhizomes yields. Other PGRs or chemical application which could reduce the growth inhibitor substances or stimulate the growth promoter substances might be fascinated for the growers although our study was unsuccessful to find the appropriate technique.

Results from this study were led to the conclusions as followed;

1. Off-season (OS) cropping of *Curcuma alismatifolia* Gagnep. increased endogenous ABA and *t*-ZR concentrations and other biochemical substances in various organs at different growth stages, led to depress shoot growth, but promote rhizomes yields.

2. The distinct environmental factors at least, short day length (SDL) and low night temperature (LNT) differently induced the endogenous hormonal and other biochemical changes in *C. alismatifolia* Gagnep.

3. SDL condition increased ABA concentration in leaves and *t*-ZR concentration in rhizomes and storage roots. It seemed to reduce other biochemical substances in overall, except the total free amino acids concentrations, led to promote rhizome yields in *Curcuma* plants.

4. LNT condition decreased *t*-ZR concentration in underground organs. It seemed to reduce other biochemical substances in various organs, led to decreased flower quality in *Curcuma* plants.

5. Under the OS condition, night interruption with supplemental lighting for 2 h and 100 mgL^{-1} of GA_3 application recommended to promote flower quality, but less productive rhizomes yields, although it could not reduce ABA concentration in all plant parts.