Yearly Difference in Normalised Seed Weight of Cultivated *Iris dichotoma* Pall in Mongolia

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**ABSTRACT**

Maximum of mean seed weight was observed at 1997 while normalised seed weight was significantly higher at 1982 and 1995, compared with other years. Seed weight variation is positively correlated with mean seed weight for earlier rainy season years, excluding later rainy season years (1982 and 1995). Low and high seed weight variation associated for years with colder and wetter in May and hotter and drier in May, suggesting drought in May might be effective on seed weight variation of *I. dichotoma*. Moderate normalised seed weight associated for years with hotter in June while high and low normalised seed weight for years with cooler and cool in June, suggesting *I. dichotoma* might use both photosynthetic productions and underground-storage for seed maturity. Mean seed weight and seed weight variation were linked to precipitation amount whereas normalized seed weight was linked to precipitation periodicity. Seed weight variation detected delay of regrowth, caused by early drought while normalized seed weight suggested seed weight response to complete seed maturation after droughty season, using photosynthetic productions and underground-storage. The results suggest that normalized seed weight might be useful to recognize seed weight response of *I. dichotoma* for climatic factors, better than mean seed weight and seed weight variation.

**KEYWORDS** cultivated *Iris dichotoma*, normalised seed weight, drought

**INTRODUCTION**

Evolution of seed weight is governed by climatic factors (Zhang, 1998; Moles et al., 2005; Liu et al., 2014) and evaluated by spatial and temporal differences. Present study considers on temporal differences of seed weight. Aniszewski et al. (2001) found different groups of seed weight during the 10 years experiment, suggesting selection pressure. Radic et al. (2013) reported that seed weight of sunflower has significantly different between years and this difference are found with observed sterile lines and with restorer lines. Manalo et al. (1998) suggested that seed weight variation due to the difference in the climatic condition of the years was greater in non-nodulating lines than nodulating cultivars.

Narantsetseg (2015) suggested that normalised seed weight is related with climatic aridity and precipitation amount in the genus *Peganum*, based on seed weight data which collected in different botany-geographic regions in Mongolia. Then, previous study found normalised seed weight was different with seed dispersal types in *Peganum* genus and different climatic aridity, suggesting normalised seed weight could recognize seed dispersal response in different climatic aridity. This study hypothesise that normalised seed weight is useful to test seed weight response to climatic effects, better than mean seed weight and seed weight variation.

*Iris dichotoma* Pall is registered as rare species in Mongolia Red Listed Book (Erdenejav, 1987) and distributes in the botany-geographic regions Khentii, Mongol-Dahurian, Great Khingan, Middle-Khalk and Eastern Mongolia. On cultivated *I. dichotoma*, phenological (Enkhtuya, 2009), histological (Enkhtuya and Tserekhmand, 2000) and biochemical (Wirginia et al., 2015) properties of this species and their ecological factors were well documented. Also, stem height, flower number per individual and its morphology and seed number per capsule were documented but seed weight and its ecological factors are still unclear.

The purpose of this study was to describe whether mean seed weight or seed weight variation or normalised seed weight of cultivated *Iris dichotoma* differentially respond to climatic factors.

**MATERIALS AND METHODS**

Drought is one of limiting factors for plant growth. Climate data was supported by database of Institute of Meteorology and Hydrology (from 1978 to 1997). According to climate diagrams (Walter and Lieth, 1960), in the Botanical Garden, drought was not observed at 1978 (Fig. 1a) while it was observed in both spring and autumn at 1979 and 1982 (Fig. 1b, c). In other years, drought was observed in April, May, and June (Fig. 1d–h). Annual air temperature increased from 1978 to 1997, excluding 1985 which was the coldest. Between 1978 and 1983, annual air temperature (T) was less than –2.0°C while between 1989 and 1997, that was more than –1.0°C. Annual sum precipitation (PP) was PP < 200 mm at 1979 and 1989 and 200 < PP < 300

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At 1975, seeds of *I. dichotoma* were cultivated by seeds in same condition of the botanical garden. Water supply was once for week by river water for all squares where cultivated plants. Peak flowering
and fruiting time of *I. dichotoma* is in July and August (Enkhtuya, 2009). Herbaceous plants normally gave seeds in 5–6 years after propagation, as reported by Myadag (1987) and Javzan (2001). Seed maturity in each site was evaluated by weight of dry seeds as reported by Harrington (1972). Weight of a thousand seeds was measured in 10 times, using the analytic scale Shimadzu AY220 (d-0.1 mg). The C.V. of seed weight within seed sample was less than 3.0%, indicating seed weight was correctly measured. Hence, to calculate weight variation in each seed sample, we used discrimination between maximum and minimum weights. To calculate normalised seed weight (NSW), mean seed weight (MSW) was divided into seed weight variation (SWV).

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\text{NSW} = \frac{\text{MSW}}{W_{\text{max}} - W_{\text{min}}}
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where \( W_{\text{max}} \) and \( W_{\text{min}} \) represent the maximum and minimum weight of a replicate within a sample, respectively.

Tukey’s Host-Hoc test was used to detect yearly differences of mean seed weight, seed weight variation and normalised seed weight. Also, correlation between two variables was used to calculate correlation between mean seed weight and seed weight variation. Correspondences of mean seed weight, seed weight variation and normalised seed weight with air temperature and precipitation amounts in May, June, and July were calculated as one-way ANOVA.

**RESULTS**

Mean seed weight was 3.5–4.9 gr between 1978 and 1995 while 6.2 gr at 1997. Mean seed weight was 4.8 gr. Maximum of mean seed weight was observed at 1997, indicating highest of precipitation amount in July (Fig. 2a). However, seed weight variation was not significantly different among years, it was lower at 1978, 1982, and 1995 than at other years, suggesting lower precipitation amount in July (Fig. 2b). Normalised seed weight was significantly higher at 1982 and 1995, compared with other years (Fig. 2c). Yearly difference of normalised seed weight show that peak of precipitation amount was in August at 1982 and 1995.

Seed weight variation is positively correlated with mean seed weight for earlier rainy season years, excluding later rainy season years (1982 and 1995) (Fig. 3). For earlier rainy season years, annual sum precipitation was from 169 mm to 320 mm and annual air temperature was from –1.2°C to –3.7°C while for 1982 and 1995, those were from 257 mm to 318 mm and from –1.3°C to 2.0°C. The results indicated that correlation between seed weight variation and mean seed weight could not associate to annual sum precipitation and annual air temperature. Maximum air temperature within year was occurred in July for all years, suggesting correlation between seed weight variation and mean seed weight did not associate to maximum air temperature. For earlier rainy season years, peak of precipitation amount was in June and July, but for later rainy season years (1982 and 1995), it was in August.
Our results show mean seed weight and normalised seed weight of cultivated *I. dichotoma* did not correspond with climatic variables in May, such as air temperature and precipitation amount (Fig. 4a, b, c, d) but seed weight variation significantly corresponded with air temperature and precipitation amount in May (Fig. 4e, d). Colder and wetter climate was found in May at 1978, 1982 and 1995 whereas hotter and drier ones found for other years. Low and high seed weight variation associated for years with colder and wetter in May and with hotter and drier in May, suggesting drought in May might be effective on seed weight variation of *I. dichotoma*.

One-way ANOVA analysis showed that mean seed weight was insignificantly corresponded with air temperature and precipitation in June (Fig. 5a, b). Also, seed weight variation showed same results (Fig. 5c, d). Normalised seed weight significantly corresponded

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**Fig. 3** Correlation between seed weight variation and mean seed weight in different rainy season years. Solid circle, later rainy season years, open circle, earlier rainy season years.

**Fig. 4** Correspondence between mean seed weight (a, b), seed weight variation (c, d) and normalised seed weight (e, f) of cultivated *I. dichotoma* with air temperature and precipitation in May. Mean seed weight and air temperature in May (ANOVA, df = 1, SS = 1.41, MS = 1.41, F = 0.46, P = 0.522); mean seed weight and precipitation in May (ANOVA, df = 1, SS = 101.52, MS = 101.52, F = 0.78, P = 0.412); seed weight variation and air temperature in May (ANOVA, df = 1, SS = 12.1, MS = 12.1, F = 9.46, P = 0.022); seed weight variation and precipitation in May (ANOVA, df = 1, SS = 824.78, MS = 824.78, F = 82.7, P < 0.0001); normalised seed weight and air temperature in May (ANOVA, df = 2, SS = 12.99, MS = 6.49, F = 4.79, P = 0.069); normalised seed weight and precipitation in May (ANOVA, df = 2, SS = 388.5, MS = 194.25, F = 1.96, P = 0.235).

**Fig. 5** Correspondence between mean seed weight (a, b), seed weight variation (c, d) and normalised seed weight (e, f) of cultivated *I. dichotoma* with air temperature and precipitation in June. Mean seed weight and air temperature in June (ANOVA, df = 1, SS = 3.81, MS = 3.81, F = 2.59, P = 0.158); mean seed weight and precipitation in June (ANOVA, df = 1, SS = 531.98, MS = 531.98, F = 0.43, P = 0.537); seed weight variation and air temperature in June (ANOVA, df = 1, SS = 0.07, MS = 0.07, F = 0.04, P = 0.856); seed weight variation and precipitation in June (ANOVA, df = 1, SS = 19.68, MS = 19.68, F = 0.015, P = 0.907); normalised seed weight and air temperature in June (ANOVA, df = 2, SS = 8.92, MS = 4.46, F = 6.07, P = 0.045); normalised seed weight and precipitation in June (ANOVA, df = 2, SS = 1188.04, MS = 594.02, F = 0.43, P = 0.669).
with air temperature in June but insignificant with precipitation amount (Fig. 5c, d). Moderate normalised seed weight (between 9.6 and 11.1) associated for years with hotter in June (more than 15°C) while high (more than 15) and low normalised seed weight (less than 9.5) for years with cooler (between 14°C and 15°C) and cool (less than 14°C) in June. All seed weight variables of cultivated *I. dichotoma* did not correspond with air temperature and precipitation amount in July (Fig. 6a–f).

MONTHLY PRECIPITATION AMOUNT

Researchers suggested that mean seed weight is different between years, resulting in difference of annual sum precipitation (Meyer, 1997; Busso & Perryman, 2005). Also, seed weight is significantly related to climatic factors, with population sourced from hotter, more arid sites producing heavier seeds than populations from cooler and wetter sites (Konarzewski et al., 2012). Our results showed that in 1997, annual sum precipitation was moderate but monthly precipitation amount was highest in July, compared with other years. Maximum of mean seed weights was in year which is wetter in July while lower seed weight variation corresponded with years which are drier in July. Aniszewski et al. (2001) suggested that yearly difference of mean seed weight is related with selection pressure but our result showed that yearly differences of mean seed weight could indicate the effectiveness of precipitation amount in July on seed weight of cultivated *I. dichotoma*.

MONTHLY PRECIPITATION AMOUNT (March–November) explained 85% of total variation of mean seed weight in *Artemisia tridentate* (Busso and Perryman, 2005). Our results showed insignificant correspondences of mean seed weight of *I. dichotoma* with air temperature and precipitation amounts in May, June and July. But, seed weight variation significantly corresponded with air temperature and precipitation amount in May. The correspondences suggested that drought condition in May might delay vegetative growth of this species and decrease seed weight and increase seed weight variation. It means that cultivated *I. dichotoma* was stressed as drought in May and might decrease seed weight as reported by Jørgensen et al. (2011) on *Vigna subterranea*.

**DISCUSSION**

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Zhang (1998) reported that populations that had higher mean seed weight also had larger maximum and minimum seed weights and early flowering populations produced larger seeds than those that flowered later in the growing season. The correlation between seed weight variation and mean seed weight in cultivated *I. dichotoma* showed that earlier peak of precipitation might affect on both seed weight variation and mean seed weight whereas later peak of precipitation affect on mean seed weight. In natural populations, normalised seed weight could be related with precipitation, climatic aridity (Narantsetseg, 2015). Present results show that normalised seed weight of cultivated *I. dichotoma* significantly corresponded with air temperature, but not with precipitation amount, because of continuous irrigation.

**Fig. 6** Correspondence between mean seed weight (a, b), seed weight variation (c, d) and normalised seed weight (e, f) of cultivated *I. dichotoma* with air temperature and precipitation in July. Mean seed weight and air temperature in July (ANOVA, *df* = 1, SS = 2.53, *MS* = 2.53, *F* = 3.63, *P* = 0.109); mean seed weight and precipitation in July (ANOVA, *df* = 1, SS = 2278.43, *MS* = 2278.43, *F* = 4.01, *P* = 0.092); seed weight variation and air temperature in July (ANOVA, *df* = 1, SS = 0.29, *MS* = 0.29, *F* = 0.27, *P* = 0.621); seed weight variation and precipitation in July (ANOVA, *df* = 1, SS = 1155.68, *MS* = 1155.68, *F* = 1.53, *P* = 0.262); normalised seed weight and air temperature in July (ANOVA, *df* = 2, SS = 0.54, *MS* = 0.27, *F* = 0.22, *P* = 0.809); normalised seed weight and precipitation in July (ANOVA, *df* = 2, SS = 354.49, *MS* = 177.24, *F* = 0.17, *P* = 0.851).
Busso and Perryman (2005) emphasised the importance of amount and periodicity of precipitation as a major determinant of seed size. Correspondence of mean seed weight and seed weight variation with annual sum precipitation indicated that those were linked to precipitation amount. However, correspondence of normalised seed weight with annual sum precipitation suggests that it was linked to precipitation periodicity. Seed weight variation detected delay of regrowth, caused by early drought while normalised seed weight suggested seed weight response to complete seed maturation after droughty season using both photosynthetic productions and underground-storage.

The results suggest that normalised seed weight might be useful to recognize seed weight response of *I. dichotoma* to climatic factors, better than mean seed weight and seed weight variation.

**REFERENCES**

20. Tsooj, Sh. (2013). Dominant plant photosynthesis in natural zones of Mongolia. *“Bembi san”* Press, Ulaanbaatar, Mongolia. (full-text in Mongolian; summary in English)


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