

Effects of Precipitation, Air Temperature and Drought on Calyx Lobe Number of *Peganum nigellastrum* Bge (Peganaceae Van Tieghem)

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Abstract

Calyx lobe number on the first flowers of *Peganum nigellastrum* was 3-5 in the desert-steppe and 5 in the forest-steppe, but it decreased on the next flowers down to 2 or completely disappeared in the desert-steppe, and up to 3-4 in the forest-steppe. The average of 4.4-7.6 mm of precipitation and 11-13°C temperature of 10 days could be adequate for calyx maturity. Calyx could grow for at least 11 days after rainfall and decreasing mean of air temperature. The calyx on the first flowers rapidly grew, compared with that of the next flowers. Maturity rate of calyx on the next flowers was inhibited under drought. Calyx maturity on the first flowers may be completed, using an underground storage of previous year, but calyx on the next flowers may be grown, using only photosynthetic production. Dryness that continued up to 11 days can call increased calyx lobe number of *P. nigellastrum*, and dryness that continues for longer than 11 days calls the decreased calyx lobe number.

Key words: *Peganum nigellastrum*, calyx lobe number, dryness, precipitation, air temperature

Introduction

Drought affects on plant productivity, growth and morphology (Ivanov *et al.*, 2004; Fraser *et al.*, 2009; Jean-Marcel Ribaut *et al.*, 2009), as well as on cellular (Voronin *et al.*, 2003) and subcellular metabolism levels (Zelling *et al.*, 2004). This effect can be estimated by biomorphological changes of above ground biomass of dominant plants (Adar *et al.*, 2006).

The effects of precipitation, temperature (Voronin *et al.*, 2003; Fraser *et al.*, 2009) and drought (Ivanov *et al.*, 2004; Ribaut *et al.*, 2009) on leaf morphology have been described, but the effects of precipitation, temperature and drought on calyx lobe number are still unclear.

Peganum nigellastrum Bge belongs to the family Peganaceae Van Tieghem, and is adapted in the desert and desert-steppe (Shiirevdamba, 1990; Tserenkhanda, 1999; Ivanov *et al.*, 2004). This species is distinguished from other taxa of the genus by calyx leaves incised into 5-7 lobes, hispid and stolon (Bobrov, 1949; Grubov, 1982, 1998). Stolon of this species found in most regions of Mongolia, such as Khangai, Mongol-Daurian, Middle Khalkh, Depression of Great Lakes, Valley of Lakes, Gobi Altai, East Gobi, Alasha Gobi, but calyx are entire or incised into 2-7 lobes. Calyx lobe number of this species may

increase or decrease under different ecological factors.

The purpose of this study was to describe whether precipitation and air temperature and drought affects on the calyx lobe number of *P. nigellastrum* and to explain mechanisms of calyx lobe number range.

Materials and Methods

Calyx lobes of *P. nigellastrum* were sampled and counted in Dalanzadgad (N43°57'48"; E104°43'20", elev. 1461 m) and Mandalgobi cities (N45°76'08"; E106°27'62", elev. 1418 m) are located in the desert-steppe zone, and Altanbulag town (N50°31'84"; E106°48'94", elev. 690 m) in the forest-steppe zone in 2008.

Air temperature in each locality is gradually increased during growing season of *P. nigellastrum*, according to the data of Institute of Meteorology and Hydrology. The average air temperature in Dalanzadgad was higher than in other localities. Maximum air temperature was from July 6 to July 10, 2008 in Dalanzadgad, whereas it was between June 6 and June 10 in Mandalgobi, and between June 25 and June 30 in Altanbulag (Fig. 1).

Amount of precipitation by 5 days was different among the localities. Total amount

of precipitation was 25.3, 54.4 and 149.3 mm in Dalanzadgad, Mandalgobi and Altanbulag, respectively. The highest amount of precipitation in Dalanzadgad was from June 26 to June 30, whereas in Mandalgobi it was high between July 6 and July 10, and between June 21 and June 25 in Altanbulag (Fig. 1).

The frequency distribution of annual precipitation is calculated in the range (World Meteorological Organization, 1975):

$P < P_{aver} - 2std_p$ - extreme dry

$P_{aver} - 2std_p < P < P_{aver} - std_p$ - dry

$P_{aver} - std_p < P < P_{aver} + std_p$ - normal

$P > P_{aver} + std_p$ - wet

where, P is decade amount of precipitation from April to mid July, P_{aver} – long term average of precipitation, std_p – the standard deviation of 10 day precipitation, from late April to mid July.

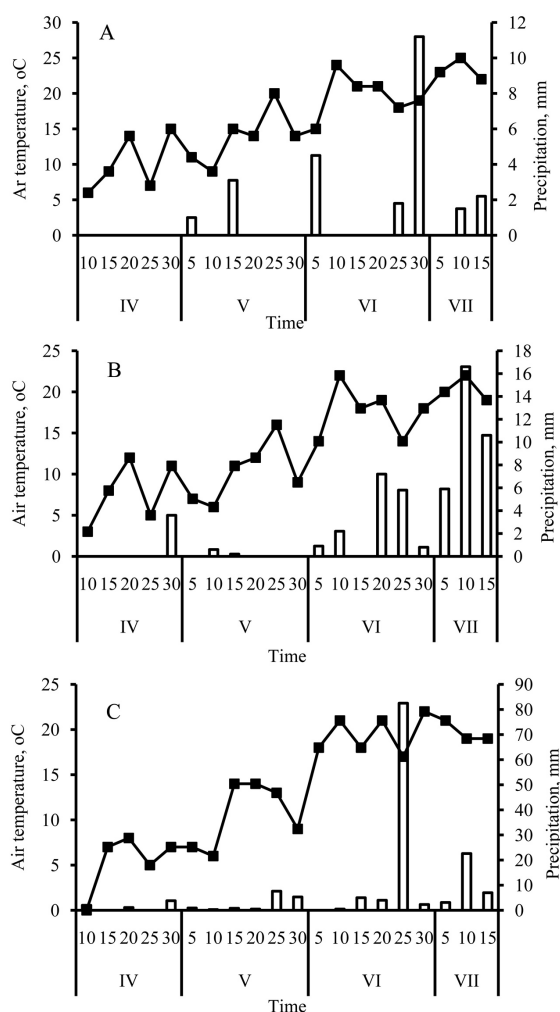


Figure 1. Seasonal changes of precipitation and air temperature by average of 5 days in each locality. A-Dalanzadgad, B-Mandalgobi, C-Altanbulag; open bar - precipitation, solid square - air temperature.

According to the criteria, the extreme dry condition in Dalanzadgad was continued during flowering season of *P. nigellastrum*. The extreme dry condition in Mandalgobi was from May 1 to June 30 and normal condition was in the first ten days of July. Dryness in Altanbulag was the lowest than in other localities. The extreme dry condition in Altanbulag occurred in the first and second ten days of May and June, and normal condition was in the third ten days of May and June.

Persistent calyx lobe number of *P. nigellastrum* did not change during the peak flowering and fruiting stages.

Calyx of *P. nigellastrum* was collected near roads, from 15 to 20 day intervals. When calyx leaves are collected, they were distinguished by the flower location on the stem. Lobes were counted on 100 calyx leaves, for each location. Differences of calyx lobe number were estimated by geographical, the flower locality on the stem and among the first, second, third and fourth flowers, using Mann-Whitney U-test (Avery, 2004). Also, correspondences among calyx lobe number and days after precipitation and the mean of 10 days' air temperature were estimated by Spearman rank correlation (r_s) and between calyx lobe number and dryness were by ANOVA, using JMP 4.0.

Results

Calyx with 3 lobes dominantly occurred on upper side of stem in Dalanzadgad and Mandalgobi, while calyx with 3-4 lobes occurred in Altanbulag. The calyx with 3-5 lobes occurred near base of stem in Dalanzadgad and Mandalgobi, whereas calyx with 5 lobes dominantly occurred in Altanbulag (Fig. 2).

Difference of calyx lobe number between flowers, where near base and upper side of stems were found in the early June in Dalanzadgad and Mandalgobi, but in late June in Altanbulag.

Calyx lobe number in Altanbulag was more than in other localities, but no difference found between Dalanzadgad and Mandalgobi, except for late June.

In early June, calyx with 3 lobes dominantly occurred on upper side of stem in Dalanzadgad and Mandalgobi, while that with 5 lobes occurred in Altanbulag. The calyx with 5 lobes was dominated near base of stem in Altanbulag,

but 3-5 lobes recorded in other regions. In late June, calyx with 3 lobes dominantly occurred on upper side of stem in Dalanzadgad and Mandalgobi, while 3-4 lobes occurred in Altanbulag (Fig. 3, Tab. 1).

In Dalanzadgad, calyx with 5 lobes dominated on the first flowers, whereas calyx lobe number decreased on the second and third flowers (Fig. 4A, Tab. 2). In Mandalgobi, the calyx with 3-5 lobes dominated on the first flowers, but the lobe number decreased down to 3 on the second and third flowers. The calyx lobe number on the fourth flowers was the fewest (Fig. 4B, Tab. 2). In Altanbulag, the calyx with 5 lobes dominated on the first and second flowers, but the calyx lobe number decreased to 3 on the third flowers (Fig. 4C, Tab. 2).

Relation between calyx lobe number and precipitation showed that maturity of calyx with 5 lobes was intense after 4.4-7.7 mm of precipitation, but the calyx with 5 lobes decreased when precipitation is less than 4.4 or more than 7.6 mm; the maturity of calyx with 3 lobes was intense after 0.8-7 mm of precipitation, whereas of the calyx with 3 lobes decreased when more than 7 mm of precipitation.

The correspondence between the calyx lobe number and mean of 10 days' air temperature illustrated that maturity of calyx with 5 lobes was intense when air temperature fluctuated between 11 to 13°C, whereas it was decreased when more than 13°C; the maturity of calyx with 3 lobes was intense when temperature is 19-21°C, but it was decreased when temperature extends above or below this range.

Calyx with 2-4 lobes or without lobe was found for 1-6 days after precipitation, whereas lobe number increased up to 5 for 7-11 days after precipitation (Fig. 5A). The calyx with 3-5 lobes was occurred when the mean of 10 days' air temperature was 11-16°C, whereas lobe number decreased to 2 or even lobes disappeared when temperature ranged between 19 and 21°C (Fig. 5B).

Calyx lobe number on the second flowers in the forest-steppe zone was similar with that of first flowers. The calyx lobe number on the first flowers of *P. nigellastrum* was more than on the next flowers because of calyx on the first flowers can grow better in spring season. The decrease of calyx lobe number on the second (excluding in the forest steppe), third and fourth flowers can

show that maturity rate of calyx on these flowers inhibited under drought.

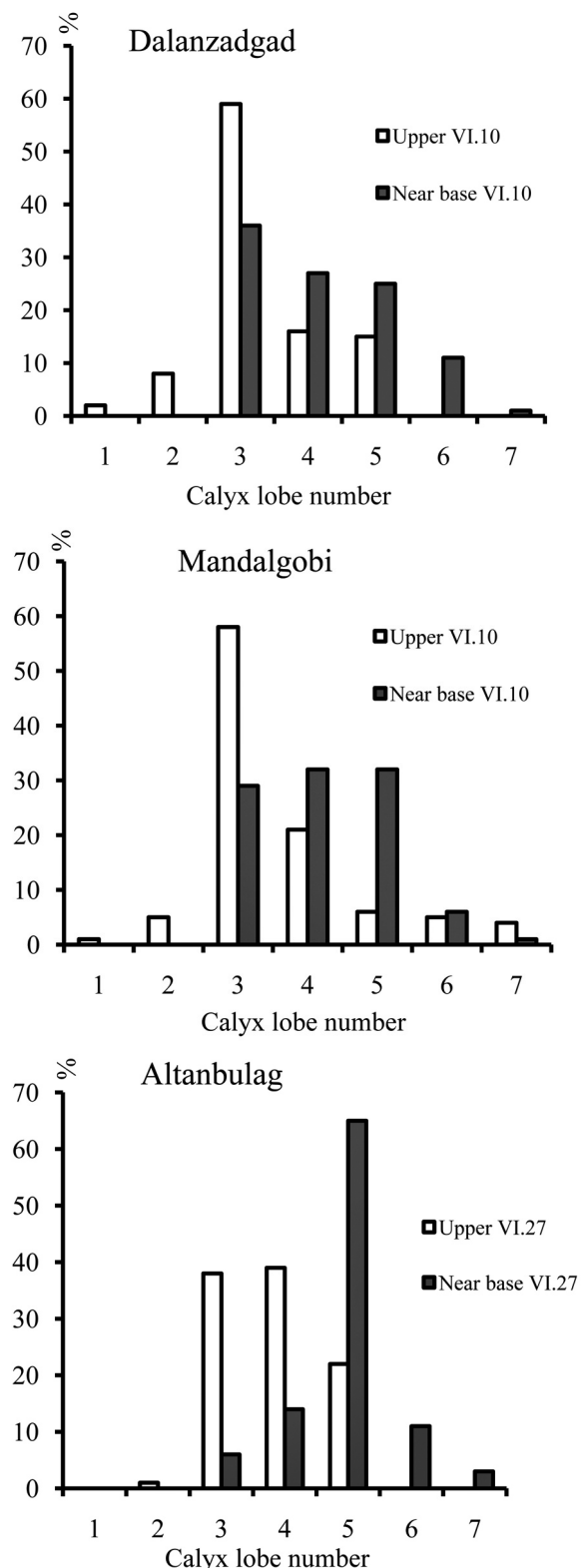


Figure 2. Differences of calyx lobe number by the flower locality on stem of *P. nigellastrum*. Dalanzadgad ($U=7013$; $z=4.92$; $P<0.0001$), Mandalgobi ($U=6798$; $z=4.39$; $P<0.0001$), Altanbulag ($U=8184$; $z=7.78$; $P<0.0001$).

Relation between calyx lobe number and day number after precipitation and air temperature show that calyx of *P. nigellastrum* could completely grow for at least 11 days after rain, when decreased mean air temperature. The precipitation of 4.4-7.6 mm and temperature of

11°C-13°C are to be adequate for calyx maturity of *P. nigellastrum*. Calyx maturity in the forest-steppe could be completed for 10 days after an adequate rain, with sufficient air temperature, but in the desert-steppe it could be for 8-11 days after insufficient rain. It means that the calyx

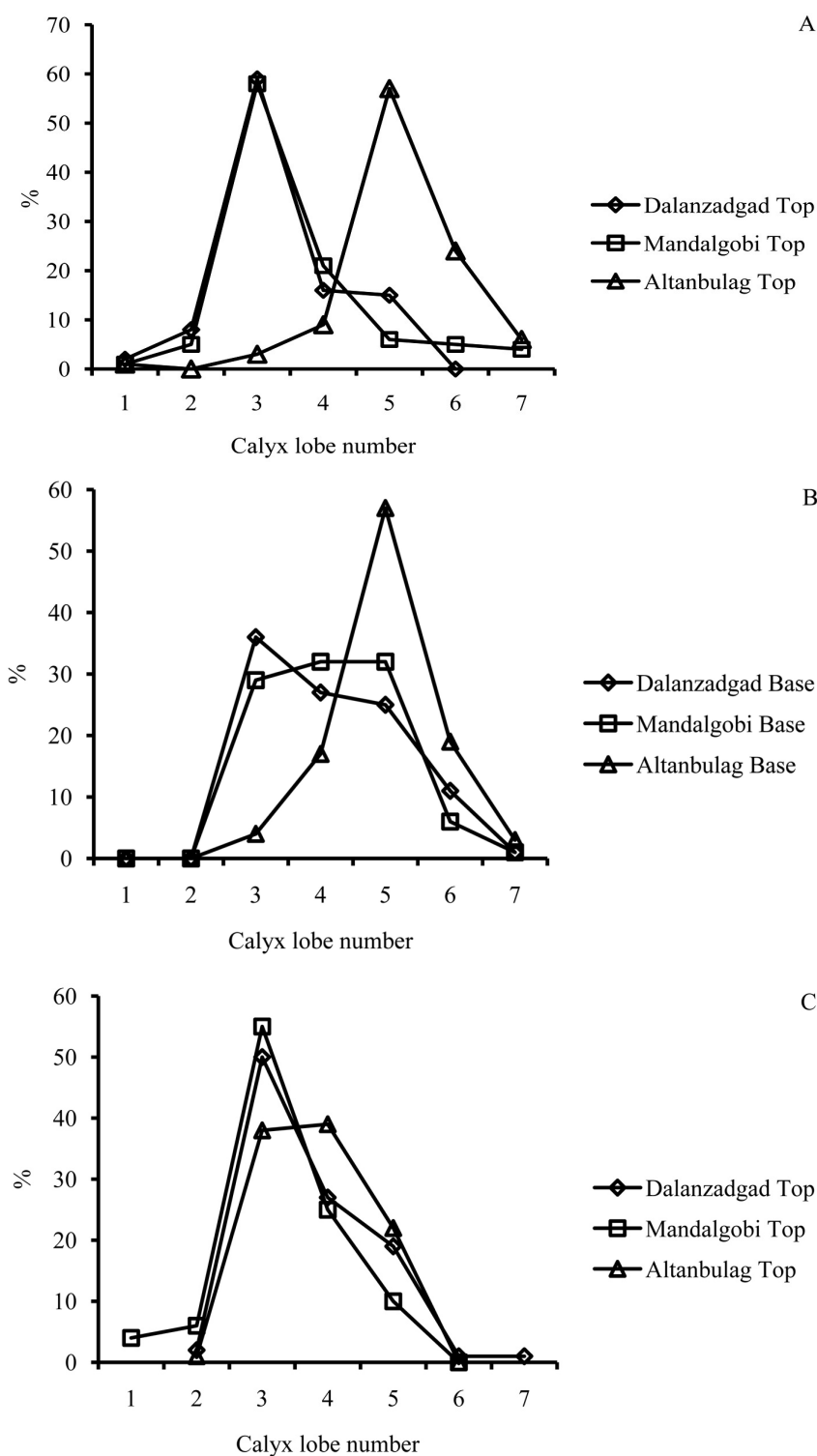


Figure 3. Geographic difference of calyx lobe number of *P. nigellastrum*. A - upper side of stem in June 5-10, B - near base of stem in June 5-10, C - upper side of stem in June 23-27.

Table 1. Geographic differences of calyx lobe number of *P.nigellastrum*, according to Mann-Whitney *U*-test (Avery, 2004)

Localities	<i>U</i>	<i>Z</i>	<i>P</i>
June 5-10, upper side of stem			
Dalanzadgad vs Mandalgobi	5394	0.96	>0.05
Dalanzadgad vs Altanbulag	8987	9.94	<0.0001*
Mandalgobi vs Altanbulag	8719	9.09	<0.0001
June 5-10, near base of stem			
Dalanzadgad vs Mandalgobi	5006	0.016	>0.05
Dalanzadgad vs Altanbulag	7292	5.6	<0.0001
Mandalgobi vs Altanbulag	7634	6.44	<0.0001
June 23-27, upper side of stem			
Dalanzadgad vs Mandalgobi	5986	2.41	<0.05
Dalanzadgad vs Altanbulag	5551	1.35	>0.05
Mandalgobi vs Altanbulag	6562	3.82	<0.0001

*-Highlight number is significantly different, according to Mann-Whitney *U*-test

Table 2. Seasonal change of calyx lobe number of *P. nigellastrum*, according to Mann-Whitney *U*-test

	<i>U</i>	<i>Z</i>	<i>P</i>
Dalanzadgad			
First flowers vs second flowers	7962	7.24	<0.001
First flowers vs third flowers	7310	5.64	<0.001
Second flowers vs third flowers	6023	2.5	<0.05
Mandalgobi			
First flowers vs second flowers	5802	1.96	<0.05
First flowers vs third flowers	6212	2.96	<0.01
First flowers vs fourth flowers	8213	7.85	<0.001
Second flowers vs third flowers	5309	0.76	>0.05
Second flowers vs fourth flowers	7704	6.61	<0.001
Third flowers vs fourth flowers	7449	5.98	<0.001
Altanbulag			
First flowers vs second flowers	5631	1.54	>0.05
First flowers vs third flowers	8836	9.37	<0.001

maturity in the desert-steppe could be completed, using an underground storage.

The dryness in the desert-steppe was stronger than in the forest steppe and then calyx lobe number in the desert-steppe decreased significantly. The frequency distribution of annual precipitation (WMO, 1975) has considered for dryness. Calyx with 3-5 lobes was dominantly occurred when dry condition continued for 10-40 days, while only 3 lobes were found when drought extended for 50-70 days. The calyx with 2 or without lobe was recorded with more than 70 days of drought.

Relationship between calyx lobe number and days after precipitations (Fig. 5A) and duration of dry condition (Fig. 6) show that different factors affected either increase or decrease of the calyx lobe number.

The results can illustrate that decrease of calyx lobe number are related with drought, because of calyx growth was inhibited under continuously dryness. Decrease of calyx lobe number on the third flowers in the forest-steppe was insignificant than in the desert-steppe, resulting sufficient precipitation in the forest-steppe, which makes better condition than

desert-steppe. Calyx on the second (excluding in Altanbulag) third and fourth flowers may be grown, using only photosynthetic production. In addition to decrease of calyx lobe number, the drought calls a reduced leaf area, especially in the upper part of the plant, as increased the erect

leaves and leaf thickness (Voronin *et al.*, 2003; Ivanov *et al.*, 2004; Fraser *et al.*, 2009; Ribaut *et al.*, 2009).

Adar *et al.* (2001) discussed about drought level estimation, using bio-morphological data (such as plant and change of leaf color and shape,

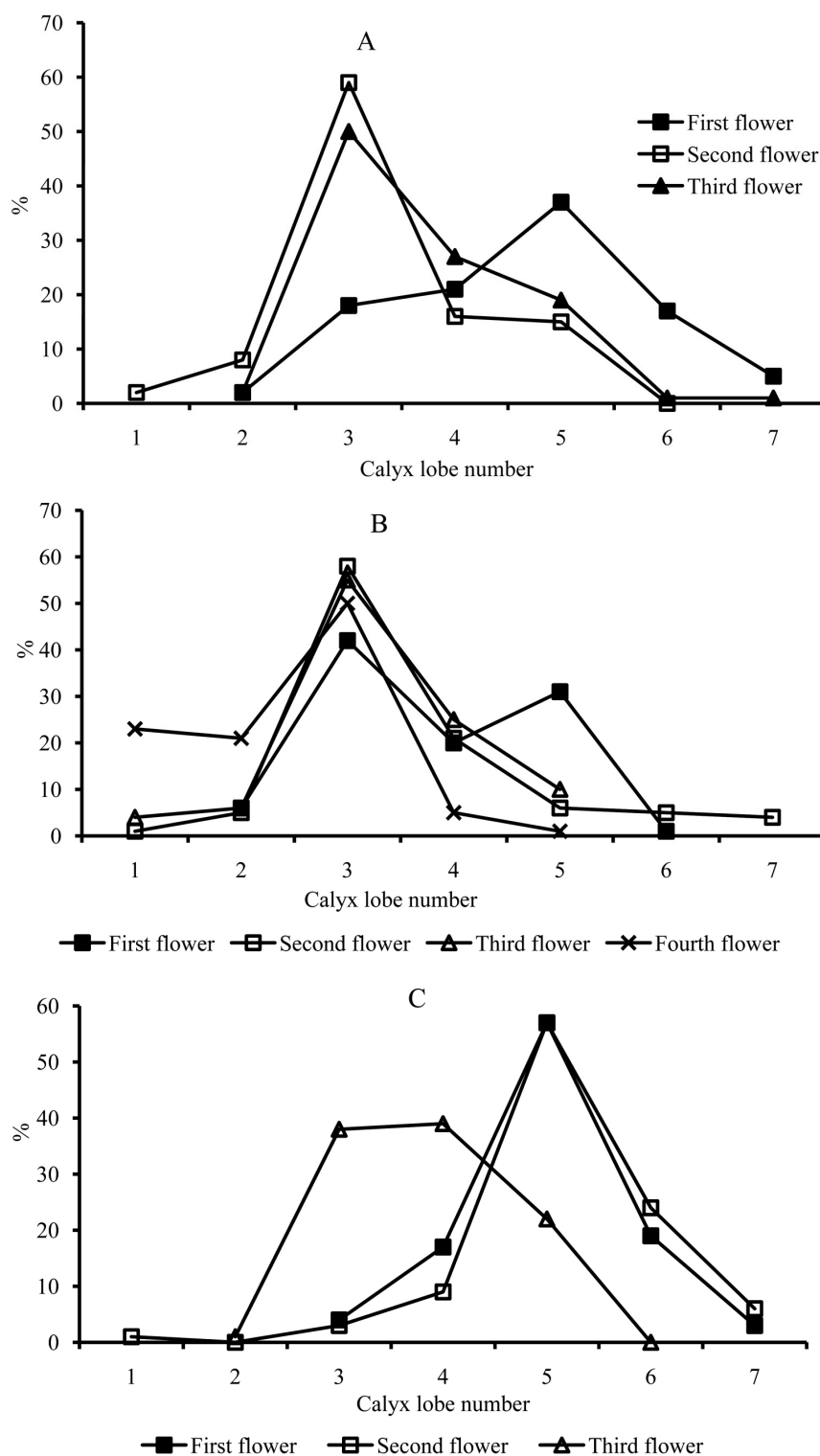


Figure 4. Seasonal change of calyx lobe number of *P. nigellastrum*. A - Dalanzadgad, B - Mandalgobi, C - Altanbulag.

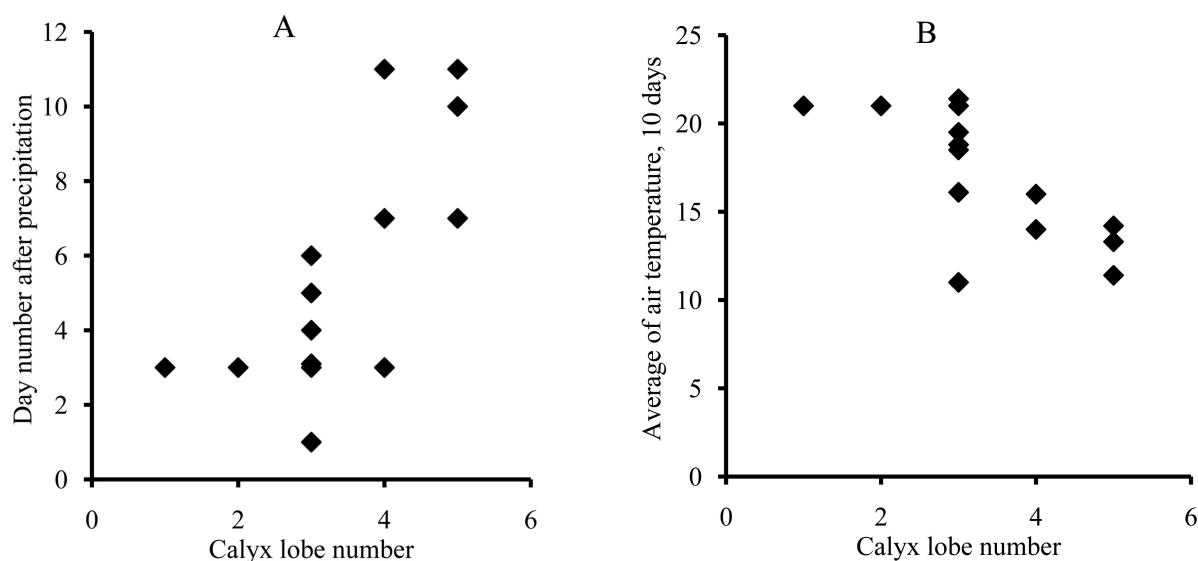


Figure 5. Relation of calyx lobe number of *P. nigellastrum* and (A) days after precipitation ($r_s=0.73$; $n=14$; $P=0.0031$); (B) the mean of 10 days' air temperature ($r_s=-0.71$; $n=14$; $P=0.0041$).

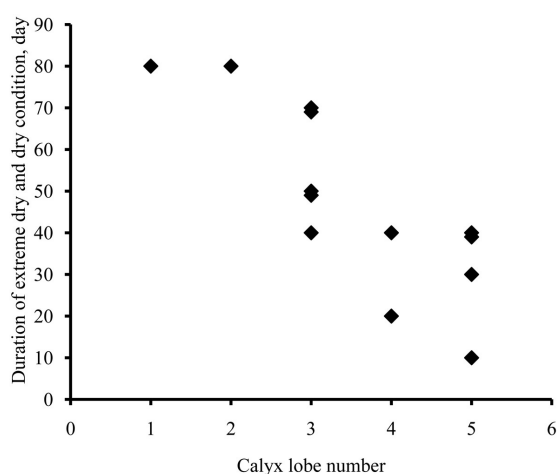


Figure 6. Effect of the duration of dry condition on calyx lobe number of *P. nigellastrum* ($N=13$; $R^2=0.74$; $P=0.0183$).

leaf fall) of dominant plants of Mongolian Gobi. Geographic difference of calyx lobe number of *P. nigellastrum* shows that dryness in Dalanzadgad and Mandalgobi was stronger than in Altanbulag, up to early June. It was progressive in Mandalgobi up to late June.

Calyx lobe number was 3-5 in the desert-steppe and 5 in the forest steppe between May 20 and May 30 but it decreased to 3 in the desert-steppe and no decrease occurred in the forest steppe between June 1 and June 10 because of drought in the forest steppe began later than in the desert-steppe. Inflorescence near base of stems begins earlier than of upper side of stems

and then calyx lobe number of flowers near base of stems can indicate dryness up to early June whereas that of flowers upper of stems indicates up to late June.

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