# Effects of Light Quality and Seed Size on Seed Germination of 14 Plant Species in Pu' er Region (Postprint)

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## Abstract

Seeds of 14 common plant species from the Pu' er region were used as experimental materials to investigate their germination characteristics under white light, darkness, red light, and blue light conditions in the laboratory, and to analyze the relationships between seed size and germination rate, germination speed, and germination onset time, thereby providing a scientific basis for local plant conservation. The results demonstrated that light quality significantly affected the germination rate and germination speed of Sifanghao, Shazhen, Jianzimu, and Huoxiangji seeds ($P<0.05$). Conversely, light quality had no significant effects on the germination rate and germination speed of ten species, including Daye Banjiuju, Yunnan Shanpihua, Choulingdan, Chesangzi, Guang' e Zhushidou, Hulucha, Yunnan Ditaohua, Xinan Subaodou, Gangling, and Zhongguo Subaodou ($P>0.05$); among these, all species except Zhongguo Subaodou exhibited germination rates below 20%, indicating dormancy. Specifically, Sifanghao seeds achieved the highest germination rates under white light (89.9%) and red light (84.7%), with the fastest germination speed under red light (4.93) and the latest germination onset under blue light (11.3 d). Shazhen seeds displayed the highest germination rate (80.4%) and fastest germination speed (2.71) under white light, whereas under darkness and blue light they showed lower germination rates (43.9% and 38%) and slower germination speeds (0.73 and 0.85); germination onset was earliest under white and red light (11 d) and latest under darkness (21.7 d). Jianzimu seeds maintained germination rates above 86% under white light, darkness, and blue light, but dropped to only 32% under red light with the slowest germination speed (1.29), and exhibited the latest germination onset under blue light (13 d). Huoxiangji seeds showed the highest germination rate and speed under red light (71.3% and 6.46, respectively) and the lowest under darkness (42.5% and 2.62, respectively). Daye Banjiuju exhibited earliest germination onset under darkness (6 d), followed by white light (7 d), with later onset under blue and red light (8 d and 7.7 d, respectively).

Across all 14 species, seed size was significantly negatively correlated with germination rate; negative correlations were also observed between seed size and both germination speed and germination onset time, though these were not significant. The relationships between seed size and germination parameters were not influenced by light quality.

## Full Text

# Effect of Light Quality and Seed Size on Seed Germination of 14 Plant Species in the Pu' er Region

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## Abstract

This study investigated the germination characteristics of 14 common plant species from the Pu' er region under laboratory conditions of white light, darkness, red light, and blue light, and analyzed the relationships between seed size and germination percentage, germination rate, and germination initiation time to provide a scientific basis for local plant conservation. The results showed that light quality had significant effects on the germination percentage and rate of *Elsholtzia blanda*, *Osyris quadripartita*, *Oxyspora paniculata*, and *Ageratum conyzoides* ($P<0.05$). Light quality had no significant effects on the germination percentage or rate of ten other species: *Vernonia volkameriifolia*, *Gordonia chrysandra*, *Laggera pterodonta*, *Dodonaea viscosa*, *Crotalaria zanzibarica*, *Tadehagi triquetrum*, *Urena lobata*, *Shuteria vestita*, *Eurya groffii*, and *Shuteria involucrata* ($P>0.05$). Except for *S. involucrata*, all these species had germination rates below 20%, indicating dormancy. *Elsholtzia blanda* seeds achieved the highest germination percentages under white light (89.9%) and red light (84.7%), with the fastest germination rate under red light (4.93) and the latest germination initiation under blue light (11.3 days). *Osyris quadripartita* seeds showed the highest germination percentage (80.4%) and fastest germination rate (2.71) under white light, but much lower percentages and rates under darkness (43.9% and 0.73) and blue light (38% and 0.85). Germination initiated earliest under white and red light (11 days) and latest under darkness (21.7 days). *Oxyspora paniculata* seeds maintained germination percentages above 86% under white light, darkness, and blue light, but only 32% under red light with the slowest germination rate (1.29), while germination initiated latest under blue light (13 days). *Ageratum conyzoides* seeds exhibited the highest germination percentage (71.3%) and rate (6.46) under red light, and the lowest under darkness (42.5% and 2.62). *Vernonia volkameriifolia* germination initiated earliest under darkness (6 days), followed by white light (7 days), and later under blue

(8 days) and red light (7.7 days). Across all 14 species, significant negative correlations were found between seed size and germination percentage; negative but non-significant correlations were observed between seed size and germination rate or initiation time. These relationships between seed size and germination parameters did not vary with light quality.

**Keywords:** light quality, blue light, red light, germination, seed size

## Introduction

Seeds represent a critical life stage for plants, forming a potential plant community, and seed germination plays a vital role in population regeneration and species persistence (Zhang, 2012). Successful germination requires appropriate conditions including light, temperature, and moisture (Yan, 2006; Baskin & Baskin, 1998; Bewley & Black, 1982; Roberts, 1986), and is also influenced by habitat factors (slope aspect, elevation) and storage conditions (cold storage, room temperature) (Cui, 2015).

Light serves as both an energy source and an environmental signal for plants (Godo, 2011). Variations in light signals/quality (wavelength) can affect various physiological processes such as cellular and intercellular differentiation, seed germination and seedling growth, photosynthesis, and flowering, with these effects depending on species, developmental stage, and organ (He, 2017). During *Arabidopsis* seed germination, green light promotes early stem elongation and antagonizes light-induced growth inhibition, while ferns under white and red light can delay senescence caused by chlorophyll loss (Burescu, 2015). Jala (2011) found that *Nepenthes mirabilis* seeds germinated earliest under white and red light, latest under green light, and showed the highest average seedling emergence rate under red light. Zhao et al. (2018) reported that red light promoted germination of *Polygala tenuifolia* seeds without affecting germination intensity. Liu et al. (2016) found red light beneficial for cucumber seed germination while blue light inhibited it. Wei et al. (2015) demonstrated that both red and blue light significantly promoted pepper seed germination, with red light being most effective. Cui et al. (2014a) showed that *Philadelphus*, *Spiraea rosthornii*, and *Spiraea alpina* seeds germinated fastest under red light and slowest under blue light, with species-specific responses to light quality. However, no studies have examined the effects of light quality (red, blue, white, darkness) on seed germination of the 14 species examined here: *Vernonia volkameriifolia*, *Gordonia chrysandra*, *Laggera pterodonta*, *Dodonaea viscosa*, *Crotalaria zanzibarica*, *Tadehagi triquetrum*, *Urena lobata*, *Shuteria vestita*, *Eurya groffii*, *Elsholtzia blanda*, *Osyris quadripartita*, *Oxyspora paniculata*, *Ageratum conyzoides*, and *Shuteria involucrata*.

Seed size represents a crucial trait in seed plants. The evolutionary potential for dispersal and establishment is conditioned by seed size, while natural selection on seed size is shaped by a species' dispersal and establishment strategies. As the beginning of the plant life cycle, germination significantly influences subse-

quent life stages, and seed size—central to plant life history—inevitably affects germination strategies (Wang, 2011). The relationship between seed size and germination has attracted considerable ecological interest and has been investigated across floras, families, genera, and species. Haiyan Bu (2007) studied 570 species on the eastern Qinghai-Tibetan Plateau, finding that larger (heavier) seeds had lower germination percentages but earlier germination initiation. Cui et al. (2008) examined 43 shrub species on the eastern Qinghai-Tibetan Plateau, revealing significant negative correlations between seed size and both germination percentage and rate. Wang et al. (2007) compared mesophytes and xerophytes, finding significant negative correlations between seed size and germination parameters in mesophytes but no relationship in xerophytes. Zong et al. (2006) found significant negative correlations between seed size and germination rate but not germination percentage among 51 Asteraceae species on the Tibetan Plateau. Cui et al. (2010) studied 11 *Berberis* species, reporting significant negative correlations between seed size and germination percentage, rate, and duration, with larger (heavier) seeds initiating germination earlier. These studies were conducted within specific floras, but no research has examined the relationship between seed size and germination capacity in the Pu' er region flora.

This study investigated 14 common plant species from the Pu' er region, representing canopy, shrub, and herbaceous layers. We addressed two questions: (1) Does light quality affect seed germination characteristics? (2) What is the relationship between seed size and germination, and does this relationship vary with light quality? This research aims to provide data support for germplasm resource conservation in the Pu' er region.

## Materials and Methods

### 1.1 Study Area Overview

The study was conducted in Simao District, Pu' er City, located at 22°27 - 23°06 N, 100°19 -101°27 E, with elevations ranging from 578 to 2,154 m. The region has a mean annual temperature of 17.9 °C, a frost-free period of 315 days, and mean annual precipitation of 1,517.8 mm, characterized by a subtropical plateau monsoon climate with low latitude, high temperature, abundant rainfall, and calm winds. Winters are mild, summers are moderate, and the terrain features gentle slopes with varied topography (Cui, 2014b).

### 1.2 Seed Collection and Processing

Seeds were collected from September to December 2016 in the Folian Mountain and Nahe Reservoir areas of Simao District, Pu' er City. Seeds of each species were harvested from at least 20 individual plants at elevations between 1,238 and 1,705 m, thoroughly mixed, air-dried, and stored dry at room temperature (Cui, 2014b).

### 1.3 Seed Size Measurement

For each species, three batches of 1,000 dry seeds were weighed, and the mean value was recorded as the 1,000-grain weight (Cui, 2014a).

### 1.4 Experimental Methods

Germination experiments were conducted after 60 days of dry storage. Germination temperature was set at alternating 10 °C/25 °C. Light treatments included: white light (24 h), darkness (24 h), red light (24 h, wavelength 660 nm), and blue light (24 h, wavelength 447 nm). For each species and treatment, 50 plump seeds were placed in 90 mm Petri dishes lined with two layers of filter paper, with three replicates per treatment. Distilled water was added daily to maintain filter paper moisture (Cui, 2014a, 2014c). Germination was checked every 24 h; seeds in darkness were examined under green light. Seeds were considered germinated upon radicle emergence and were removed. Experiments lasted 40 days, after which ungerminated seeds were tested for viability using the TTC method. Species with germination rates below 20% were considered dormant (Jurado & Flores, 2005; Cui, 2014a).

### 1.5 Analysis Methods

One-way ANOVA was used to test the effects of light quality on germination percentage and rate, with least significant difference (LSD) tests for pairwise comparisons. Pearson correlation analysis was performed on the relationships between seed size and germination percentage, rate, and initiation time (with germination percentage, rate, initiation time, and seed size arcsine-transformed) (Cui, 2008, 2014a, 2014b, 2014c, 2015). Key indices included: germination percentage (percentage of viable seeds germinated by experiment end) and germination rate index (GR) = $G/T + G/T + \cdots + G/T$, where T is the day of germination and G is the germination percentage at time t (Cui, 2008, 2014a, 2014b, 2014c, 2015). Statistical analyses were conducted using SPSS 17.0.

## Results

### 2.1 Effects of Different Light Qualities on Seed Germination

Among the 14 species, nine (*Vernonia volkameriifolia*, *Gordonia chrysandra*, *Laggera pterodonta*, *Dodonaea viscosa*, *Crotalaria zanzibarica*, *Tadehagi triquetrum*, *Urena lobata*, *Shuteria vestita*, and *Eurya groffii*) had germination rates below 20% under all four light conditions (Table 1).

One-way ANOVA revealed that light quality had extremely significant effects on germination percentage of *Elsholtzia blanda*, *Osyris quadripartita*, and *Oxyspora paniculata* ($P<0.001$), and significant effects on *Ageratum conyzoides* ($P<0.05$). Light quality had no significant effects on germination percentage of the remaining ten species (Table 2).

*Elsholtzia blanda* seeds achieved germination percentages above 84% under white light (89.9%) and red light (84.7%), significantly higher than under darkness (44.3%) and blue light (61.6%). *Osyris quadripartita* seeds showed significantly higher germination percentages under white light (80.4%) and red light (70.7%) compared to darkness (43.9%) and blue light (38%). *Oxyspora paniculata* maintained germination percentages above 86% under white light, darkness, and blue light, but only 32% under red light. *Ageratum conyzoides* achieved the highest germination percentage under red light (71.3%), slightly higher than under white (68.8%) and blue light (62.8%), with darkness producing the lowest percentage (42.5%), significantly lower than the other three treatments.

**2.1.2 Effects of Light Quality on Germination Rate** Light quality had extremely significant effects on germination rate of *Ageratum conyzoides*, *Osyris quadripartita*, and *Oxyspora paniculata* ($P<0.001$), and significant effects on *Elsholtzia blanda* ($P<0.05$). No significant effects were observed for the other ten species (Table 2).

*Elsholtzia blanda* seeds germinated fastest under red light (GR=4.93), significantly faster than under other conditions, with the slowest rate under blue light (GR=1.36). *Osyris quadripartita* seeds germinated fastest under white light (GR=2.73), significantly faster than under the other three conditions, with the slowest rate under darkness (GR=0.71). *Oxyspora paniculata* seeds germinated fastest under white light and darkness (GR=3.52 and 3.53) and slowest under red light (GR=1.29). *Ageratum conyzoides* seeds germinated fastest under red light (GR=6.46), slightly faster than under white light (GR=6.39), and significantly faster than under other conditions.

**2.1.3 Effects of Light Quality on Germination Initiation Time** Light quality significantly affected germination initiation time in five species: *Vernonia volkameriifolia*, *Urena lobata*, *Elsholtzia blanda*, *Osyris quadripartita*, and *Oxyspora paniculata* ($P<0.05$), with no significant effects on the remaining species.

*Elsholtzia blanda* seeds initiated germination on day 5 under white, red, and dark conditions, but not until day 11 under blue light. *Osyris quadripartita* seeds began germinating earliest under red and white light (11 days) and latest under darkness (21.67 days). *Oxyspora paniculata* seeds showed significantly delayed initiation under blue light (13 days) compared to other conditions. *Vernonia volkameriifolia* germinated earliest under darkness (6 days), followed by white light (7 days), with later initiation under blue (8 days) and red light (7.7 days).

### 2.2 Effects of Seed Size on Seed Germination

Among the 14 species examined, seed size varied considerably, with a mean weight of 4.249 mg/seed. The largest seeds were *Gordonia chrysandra* (24.25 mg/seed) and the smallest were *Osyris quadripartita* (0.02 mg/seed) (Table 1).

Correlation analysis revealed significant negative relationships between seed size and germination percentage across all 14 species under white light, darkness, blue light, and red light (Figure 1). Negative but non-significant relationships were observed between seed size and both germination rate and initiation time.

Separate analyses of four Asteraceae species and four Papilionaceae species showed no significant correlations between seed size and germination percentage or rate under any light condition.

[Figure 1: see original paper]

## Discussion

Nine of the 14 species (*Vernonia volkameriifolia*, *Gordonia chrysandra*, *Laggera pterodonta*, *Dodonaea viscosa*, *Crotalaria zanzibarica*, *Tadehagi triquetrum*, *Urena lobata*, *Shuteria vestita*, and *Eurya groffii*) remained dormant under all four light conditions in our experiments (Jurado & Flores, 2005), indicating that the experimental conditions—alternating temperature and varied light quality—could not break their dormancy, warranting further investigation.

*Elsholtzia blanda* and *Osyris quadripartita* showed similar light requirements, with white and red light promoting germination and darkness and blue light inhibiting it. This likely reflects the promotive effect of red light and the red-orange region of white light (660 nm wavelength) on germination and dormancy release, consistent with Borthwick' s (1954) findings in lettuce. Red light (660 nm) can increase phytochrome activity, promote chlorophyll formation, and regulate seed germination and hypocotyl elongation, thereby releasing dormancy (Cui, 2014a). Under blue light and darkness, light conditions fail to meet these requirements, resulting in significantly reduced germination percentages, as reported in studies on *Philadelphus* (Cui et al., 2015) and *Ageratina adenophora* (Jiang et al., 2012). Overall, *Elsholtzia blanda*, *Osyris quadripartita*, and *Ageratum conyzoides* are light-demanding species, but their wavelength requirements differ, with germination rates decreasing in darkness.

*Oxyspora paniculata* seeds showed no light/dark requirement, yet red light inhibited germination—a previously unreported phenomenon that may relate to exposure duration. Some studies indicate that brief light exposure can release dormancy, while prolonged red light exposure may induce secondary dormancy in *Oxyspora paniculata*. The earliest germination initiation of *Osyris quadripartita* under red and white light (11 days) aligns with Jala' s (2011) findings for *Nepenthes mirabilis*. Additionally, *Vernonia volkameriifolia* and *Oxyspora paniculata* germinated earliest in darkness, *Urena lobata* in red light, and *Elsholtzia blanda* in white, red, and dark conditions, demonstrating species-specific responses in germination timing to light quality. These differences may relate to plant life forms, as phanerophytes can emerge from soil depths (in darkness) due to greater seed reserves (Rojas, 1997).

Significant negative correlations between seed size and germination percentage

were observed across all light conditions, with non-significant negative relationships for germination rate and initiation time. These findings align with previous studies (Cui et al., 2008; Bu, 2007; Wang et al., 2007; Zong et al., 2006). However, we found that the relationship between seed size and germination percentage did not differ among light qualities. Larger seeds produce seedlings with higher survival and reproductive capacity, are less affected by density pressures, and confer advantages during seedling establishment through greater nutrient reserves for overcoming harsh conditions. In contrast, smaller seeds have competitive advantages through numerous offspring, small size, strong dispersal capacity, and higher germination percentages for colonizing existing vegetation (Wulff, 1986; Cui, 2008), though they face disadvantages later in development that require higher germination rates to compensate. Seed size is ultimately determined by the maternal parent, and selection on seed size may have greater evolutionary significance from the parental perspective.

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*Note: Figure translations are in progress. See original paper for figures.*