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Effects of Colored Light on Seed Germination©

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INTRODUCTION

Since plants are photosynthetic organisms it is no surprise that seed germination if based upon the affects of light as well. Seed can be roughly divided into two categories, those that require light to germinate and those that germinate in the dark. Each category provides the germinating seedlings with a definitive survival strategy. Foxtail grass, *Setaria* sp., will not germinate unless the seed are exposed to light. Anecdotal accounts have suggested that *Setaria* seed has a life span of greater than 40 years and can germinate at any point along that life span provided basic environmental elements are met, which includes exposure to light.

According to Sokol and Stross (1992) the germination of most seeds, spores of ferns, lichens, mosses, and related plants is activated by brief exposures to red light. The exact mechanism is known as the phytochrome response and it is based upon the role of the various photoreceptor proteins, Phytochrome A, Phytochrome B, and Phytochrome C and how they are affected by the influx of red and far red light. The ratio of which regulates the activity of germinating seeds. In addition to the phytochromes there are other light initiating germination pigment systems, one or more for blue light and one for ultraviolet A and one for Ultraviolet B, called crytochromes (Chory, 1996). Cross (2006 Internet citation) also lists some twenty four different functions that Phytochrome activity affects in germinating and developing plants. The phytochrome and cytochrome responses to light can be modulated and influenced by a series of screening pigments in seed batches (Cone and Kendrick, 1985).

Other factors influencing the light receptive phytochrome and presumably the cyrptochromes are certain chemicals found within the seeds and temperature fluctuations (Philips, 1961; Small, 1979; Takaki, 1985) exogeneously applied chemicals such as nitrate, thiourea, and cyanides (Probert et al., 1987) and stratification requirements (Schutz, 2002). Takaki (1985) goes on to say that exposure to high temperatures can induce a non-phytochrome-related process that overrides the phytochrome response.

A survey of the literature shows that most phytochrome studies have been with either darkness, red light, or white light (Chory, 1996). Kavalen and Appelgren's work (Kvaalen and Appelgren, 1999) is a notable exception with a study on the germination of somatic embryos and seeds in *Picea abies* with colored lights.

The work here is to explore the possible effects of colored lights on the germination of *Impatiens walleriana* Accent Series, white, (Germania Seed Co. Chicago, Illinois) a light germinator; *Delphinium* Magic Fountains Series, pure white (Ferry Morris, Fulton, Kentucky) a dark germinator; *Eragrostis trichodes*, (Bammert Seed, Muleshoe, Texas) a light germinator; and *Cortaderia selloana*, (Germania Seed Company, Chicago, Illinois), a light germinator.

METHODS

In preparation for germination, seed was counted out in specific quantities and placed in standard sized (6 cm) polycarbonate petri dishes lined with two layers of 5-cm square common paper towel. Towels were moistened with 6 ml of nontreated tap water and seed was randomly dispersed over the squares. Petri lids were fitted but not sealed. The loaded petri dishes were then placed in trapezoid wire-framed pyramids, 10 cm wide at the top, 12 cm at the bottom with a distance of 12 cm from bottom to top internally covered with the appropriate plastic filter according to color. Two petri dishes per each structure and two sets of structures placed at random intervals so that no one color is in the same place at the same time. Polypropylene film used as light filters were from Paper Mart, Los Angeles, California, with the following color ranges; red (W4720130), orange (W4720140), yellow (W4720150), spring green (W4720168), sky blue (W4720170), purple (W4720186), clear (W4720101), and fuchsia pink (W4720133).

Temperatures were monitored and were kept uniform with a supplemental bottom heat system set at 20 °C +/-1 °C. Light was provided by two sets of florescent tubes, GE F40KB, General Electric, 38 cm above the level of the petri dishes. Light was set for a 12-h period followed by a 12-h dark period. Light intensities for the various colored filters are listed in Table 1 as measured by a Lux Light Meter (Velleman Components, Fort Worth, Texas, <Velleman.com>).

Petri dishes were checked daily for emergence of a radical which was used as an indicator of germination. Petri dishes for *Eragrostis trichodes* were checked every 12 h to determine if there were differences in germination during the light period or the dark period. Emergence of a cotyledon was not necessarily considered. Counts were made until no further germination was detected or when germination in a particular color was maximized.

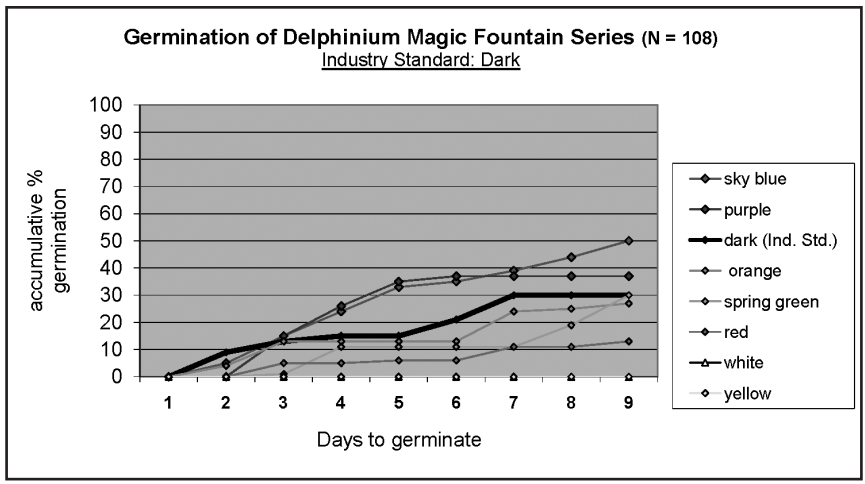

Figure 1. Germination of *Delphinium* Magic Fountain Series, (N = 108), industry standard: dark.

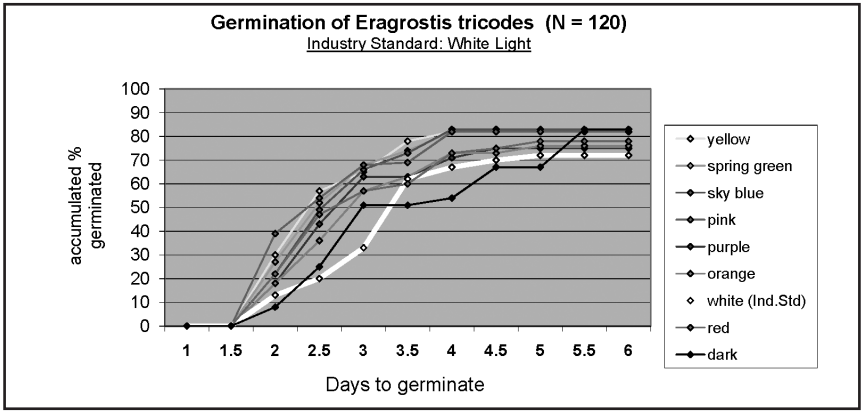

Figure 2. Germination of *Impatiens* White Accent Series, (N = 240), industry standard: white light.

RESULTS

The best method of determining changes with regard to light variations is represented by graphs for each species plotting days to germinate Vs accumulative percent germination. For clarity each plant will be assessed separately.

Normal germination requirements for *Delphinium* Magic Fountains Series, pure white is considered darkness and upon germination seedlings are moved into a lighted area (Riley, 1978). Therefore darkness was provided here as the control. Figure 1 shows a 9-day period for the testing of *Delphinium* Magic Fountains Series, pure white. Other seed treatments were the colors, orange, yellow, green, blue, purple, and white light. Three things are immediately apparent. As expected seed exposed to white and yellow light did not germinate, indicating that some inhibition process is at play. Seeds germinated under darkness, blue, and orange light started to germinate at 24 h. Seeds exposed to purple, red, and green commenced at 48 h. But beyond that, two light treatments, blue and purple started to reach peak germination at 5 days and either leveled out at 38% for purple light or climbed to 50% for blue light. This pattern was followed by darkness, the industry recommendation, where a peak germination percentage was not reached until Day 7 and then leveled out at 30%. Oddly orange followed a similar timing profile as darkness but the overall germination peak was lower and not reached until 9 days. Green light was much slower to germinate but also reached a peak at 9 days. Red light provided a very slow germination rate and a poor peak percentage at 9 days of 15%. Yellow seems to be inhibitory and so is white light.

Figure 2 presents results of light variations for *I.* Accent Series, white. Under normal conditions this plant is considered a light germinator and so white light was considered to be the industry standard and the control. The *Impatiens* study was conducted for 13 days. Once again, there was an immediate observation of a divergence of start times for germination. Seed exposed to white light and blue light did not initiate germination until Day 7. Seeds exposed to purple, green, orange, red and yellow started to germinate at Day 6. Peak germination percentages were reached at Day 10 for purple at 88% and followed on Day 11 by for yellow and green

light at 98% and blue at 88%. White-light-treated seedlings did reach a germination peak until Day 12 and leveled out at 95%. Orange and red light did not allow seed germination to peak until Day 13 with peaks at 95% and 93%, respectively.

Eragrostis trichodes, (Fig. 3) is also a light germinator (Riley, 1978) as are most if not all grasses. It germinates quickly and peaks can be reached in as little as 4 days. Yellow, blue, green, and pink light all reached at peak at 4 days with percentages of 83%–85%. Orange-, red-, and white-light treated seed did not reach peak germination until Day 5 with percentages of 78%, 75%, and 70%, respectively. Dark-treated seedlings did not peak until 5-½ days and reached percentages of 85%, although grossly distorted. In all cases colored lights positively influenced the germination of the seeds in comparison to white light. Only darkness was a less desirable situation for seed germination.

With regards to evaluation of germination the data was tabulated every 12 h instead of once a day. The hope was that there would a noticeable change from night to day, however, the data did not support this and there was no readily discernable difference between the number of seed germinating at night as opposed to the number germinating during the lighted hours. It would be interesting to try to detect this but as of this set of data nothing could be found.

The results of *C. selloana*, a grass that requires light to germinate, are shown in Figure 4. All treatments reached peaks on or before Day 7. Of significant note, pink light stimulated germination with the greatest amount of overall percentage and a very rapid rate of germination with near peaks at Day 5 and reaching a full peak at Day 7. Pink was followed in effectiveness with yellow light at nearly the same level of final germination percentage. Green and red light trailed at a close pace as did purple, with pink and yellow having the best overall performance for both time and percentage germinated. Orange was slightly better than white light and blue light was the least effective and closely mimicked white light for poor results.

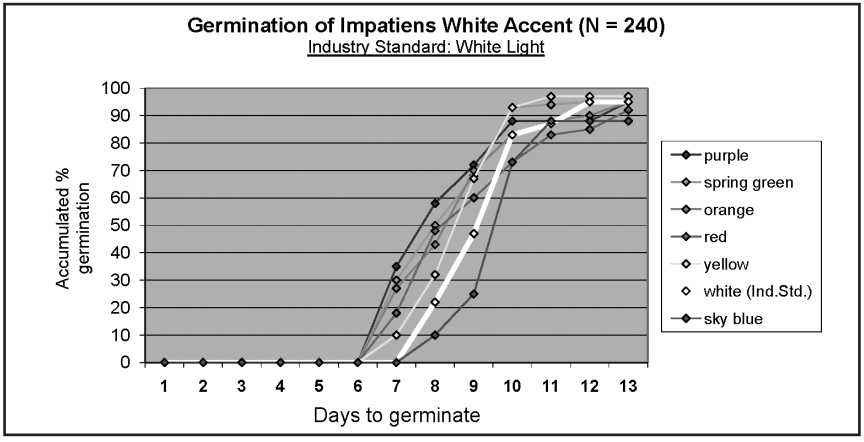

Figure 3. Germination of *Eragrostis tricodes,* (N = 120), industry standard: white light.

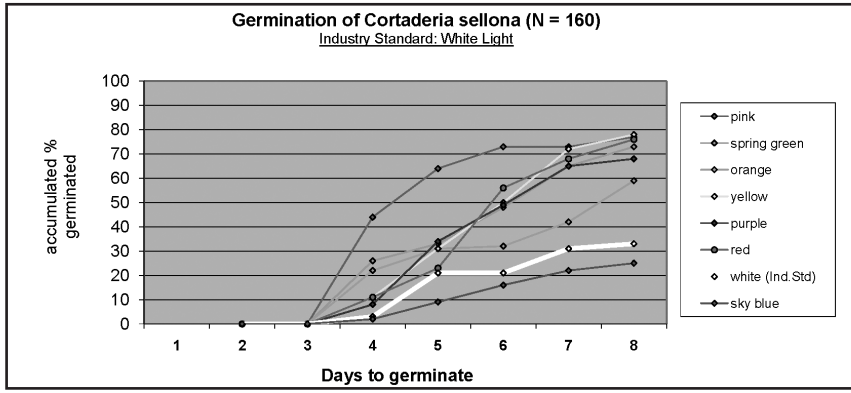

Figure 4. Germination of *Cortaderia sellona,* (N = 160), industry standard: white light.

DISCUSSION

One overly apparent trend is that no matter what the standard treatment for germinating be it white light or darkness, there are colored light situations that are as good or better than what is commonly used. Seed germinated in the dark, requires quite a bit of diligence to ascertain the extent of germination and should require the use of a safe light which will not disrupt the germination process. If the seedlings are grown under blue or purple light this problem can be eliminated. Part of the problem with delphinium seedling is if removed too early then part of the germination potential is lost and if allowed to remain too long then the resultant seedlings are prone to disfigurement as well as being potentially damaged by bright light causing photodegredation of cells, in short, sunburn for plants. A very specific acclimation and adjustment process is necessary to bring dark-germinated seedlings into normal light environments. This can be a potentially damaging problem for sensitive seedlings.

It is difficult to believe that a yellow light source would inhibit delphinium seed germination and the more likely scenario is that yellow filtered light does not contain any triggering wavelengths such as blue and purple and hence delphinium seed does not respond to yellow light. Since blue and purple light does positively affect delphinium seed it also seems that the phytochrome system may not be the single triggering mechanism for germination and the cytochrome system utilizing blue and ultraviolet wavelengths may be responsible as well. White light should be thought to be inhibitory because it does contain wavelengths such as far red which can short circuit phytochrome response. Delphinium seed apparently utilizes more than one system to initiate seed germination.

What is even more interesting is that in all four cases germination percentage was as good as and often better than the control treatments. With *Eragrostis* the percentage difference from the control (white light) to yellow, green, or pink light was as much as 10% better for the colored treatments. Impatiens White Accent showed no difference in percent germination but had a 1 day lead in germinating. On the other hand with *Delphinium* Magic Fountains Dwarf Strains, blue and purple light gave higher germination percentages as well as a reduction in the number of days to germinate. Dark control seed germination never did approach

the efficiency of the blue and purple light treatments. Difference of percent germinated was as much as 20% in favor of the blue and purple treatments and a modest 5% gain on germination was accomplished some two days earlier compared to the dark treatment.

In looking at the light intensities (Table 1) a question could be asked does the light intensity as measured for the various colors in lux affect the outcome. In essence, possibly, but in looking at *E. trichodes* seed, all of the colored light treatments were superior to the control of white light, even though the white light exceeded the lux values of purple, blue, and red and was close to being even with pink and green. Only in the case of yellow and orange were lux values in excess of white light.

Table 1. Light levels for seed germination studies in lux.

Color	Lux
Clear	958
Purple	386
Red	545
Yellow	1475
Green	1010–1350
Orange	1600–1635
Blue	460
Pink	860

Nyman's work with *Pinus sylvestris* (Nyman, 1961) showed a very positive response to exposure to red light with a single exposure of 30 min followed by darkness. He also found that the Rred light response could be reversed by a subsequent exposure to far red light. In the present work it seems as though the germination response due to light was partially phytochrome but other systems might be at play as well. He goes on to say that he presumed that a green "safe" light was sufficient to prevent light contamination of the test seed. However the work here suggests that even green light in the instance of *E. trichodes* and *I.* Accent Series, there were positive affects on germination. It is also interesting that green did not exhibit the same affect with the dark requiring delphinium seed. It seems then that mechanism of germination response for light requiring seeds is different from that of dark requiring seed.

Nyman (Nyman, 1961) does say that the light requirement for germination depends upon the seed coat and that the removal or puncturing of the seed coat of *P. sylvestris* was sufficient to trigger germination even in the dark. He also found that this situation can be initiated by stratification of *P. sylvestris* seed. Perhaps this suggestion has undiscovered merit and could a chemical or physical mechanism be developed that would prime to seed to germinate either with a particular color or with impunity to particular colors, including white light.

With reference to *C. selloana*, (Fig. 4), it is curious that while white light is considered by the industry to be the norm for germinating seed of grasses, these results indicate a high selectivity towards certain wavelengths. White light is a complex mixture of wavelengths and supplies both some of the desired elements but more

importantly it appears that presence of inhibitory colors of certain wavelengths such as blue contained within white light can over-ride the positive affects of red, yellow, and green. Pink can be thought of as a mixture of red and orange and perhaps yellow and appears to be synergistic. It would be prudent to make filters of just those colors in various combinations and see if that is indeed the case.

INTERPRETATION FOR THE INDUSTRY

From a practical level this work tells us a couple of things. One, colored light can influence germination of seed regardless of the requirement for white light or darkness. Second, in some instances germination percentage over a specified period of time can be enhanced particularly if the seed has not gone through an enhancement process, i.e., wild collected seed. A third facet suggests that the germination of seed can be tailored to meet certain time frames by adjustment of particular colors.

If a system can be developed to take advantage of a 2 or more day acceleration of seed germination the resulting time savings could be extrapolated over a 6 month or 1 year period. Over the course of a year, it seems logical that an availability of bench space could be increased by as much as 72 days. Since bench space could be tabulated as dollars per day, this could be a substantial saving and allow for as much as a 20% increase in productivity of certain seed-grown crops.

Finally if distinct crops were selected based upon propensity to germinate upon exposure to specific colored light, it seems plausible that improved varieties could be developed after several generations that would respond to that unique light and have increased productivity.

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