

Effects of GNI Directed Energy on Germination of Redroot Pigweed Seeds

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Objective

Evaluate the germination response of redroot pigweed seeds (*Amaranthus retroflexus*) treated with directed energy (DE) (light) delivered through a Global Neighbor, Inc. (GNI) DE system.

Methods

- Seed Source: Redroot pigweed, B09-16 (Finney Farm), Doohan Lab, HCS, OARDC/OSU.
- Seed Treatment: GNI staff mixed seeds with small grain chaff and treated batches with a DE system on 12/11/20. Two different DE settings were used, with two batches of seeds/chaff per setting, for a total of 4 treatments (Setting 1: Treatment A and C; Setting 2: Treatment B and D).
- Germination Test: For each treatment, 3 replications of 100 seeds were placed in petri dishes lined with moist germination blotter, along with 3 replications of control seeds (maintained in the Doohan Lab seed cooler), for a total of 15 dishes (experimental unit = 1 petri dish of 100 seeds). Dishes were placed in a growth chamber set at 28:25 C, 16:8 hr, light:dark, and checked for germination every 1-2 days. Each count day, the number of newly germinated seeds in each dish was recorded. Water was added to dishes as necessary. The germination test was started 1/25/21 (Day 1) and the final count taken 2/3/21 (Day 10). To determine post-test seed weights, a group of 10 seeds remaining in each dish was weighed. Initial 10-seed weights (average of 3 sets of 10 seeds) were determined using seeds from source bags for each treatment.

Results

Four categories of germination were observed during the course of the germination test:

- Normal radicle: Seeds completing germination with protrusion and growth of a normal radicle (Figure 1A).
- Abnormal radicle: Seeds completing germination with protrusion and growth of a thickened, curled, stunted radicle (Figure 1B).
- Split seedcoat: Seeds showing incomplete germination as evidenced by splitting of the seedcoat adjacent to the procambium and radicle, and visible swelling of those tissues, but no radicle protrusion (Figure 1C, Figure 2).
- Ungerminated: Seeds showing no obvious visible signs of physiological activity (Figure 1D).

The total number of germinating seeds with normal radicle growth for the Control averaged 97 (out of 100) and was significantly higher than for Treatments A to D, which ranged from 0 to 1.7 seeds (Table 1, Figure 3). Germination with normal radicle growth was observed Day 3 to Day 8 for Control seeds, and Day 3 to Day 6 for treated seeds (Figure 4).

The total number of germinating seeds with an abnormal radicle was low overall, with Treatment A having the most (average of 1.7 seeds), followed by Treatment C and the Control (average of <1 seed each), and none for Treatments B and D (Table 1, Figure 3). Germination with abnormal radicle growth was observed Day 4 to Day 8 (Figure 5).

The total number of split seedcoats was highest for Treatment B (10 out of 100 seeds), followed by Treatment D (4 seeds) and lowest for the Control (0 seeds) (Table 1, Figure 3). The number of split seedcoats in Treatments A and C did not differ from the Control and Treatment D. Seedcoat splitting was observed for all DE treatments as early as Day 4 (though recording of seedcoat splitting started Day 6) and continued through Day 10 (Figure 6).

All remaining seeds not falling into one of the three previous germination categories were considered ungerminated, which accounted for the majority of seeds in dishes of Treatments A to D (Table 1, Figure 3). While these seeds showed no obvious visible signs of physiological activity, they had imbibed water, as indicated by a higher average weight of seeds remaining in petri dishes compared with weights of surplus seeds for each respective treatment (Table 2).

Discussion/Conclusions

- Redroot pigweed seed germination can be described by 3 main phases: imbibition of water, reactivation of metabolism, and protrusion of the radicle (Bewley 1997).
- Both DE settings used to treat redroot pigweed seeds resulted in little or no complete germination (protrusion of a radicle), compared with almost 100% complete germination for untreated seeds, providing strong evidence that DE can render seed tissues nonviable.
- The majority of DE-treated seeds imbibed water but remained ungerminated, showing no visible signs of physiological activity.
- Of the few DE-treated seeds that completed germination, almost half produced an abnormal (deformed) radicle.
- Some DE-treated seeds exhibited incomplete germination as indicated by a split seedcoat adjacent to the radicle and some swelling of seed tissue, but no radicle protrusion. This phenomenon was not observed in the Control, providing further evidence that DE can damage seed tissues and prevent complete germination.
- There was a subtle difference in the number of seeds with abnormal or incomplete germination between the two DE settings.
 - DE Setting 1 (Treatments A and C) resulted in a few germinated seeds with a stunted and thickened radicle, while no abnormal radicle growth was observed for DE Setting 2 (Treatments B and D).
 - However, Setting 2's Treatment B and to a lesser extent Treatment D had a higher number of seeds terminating with split seedcoats and visible swelling of seed tissue versus Setting 1 treatments.
- For each DE setting, seed germination response was generally consistent between the two batches of treated seeds. However, for Setting 2, Treatment B had significantly more split seedcoats than Treatment D, which would suggest some variation in the effect of DE on seed tissue viability.

References

Bewley, J.D. 1997. Seed germination and dormancy. *Plant Cell* 9:1055-1066.

Irving, D.W., A.A. Betschart, and R.M. Saunders. 1981. Morphological studies of *Amaranthus cruentus*. *J. Food Sci.* 46(4):1170-1174.

Table 1. Average number (out of 100) of germinated redroot pigweed seeds in different germination categories. Within each category, means followed by the same letter are not significantly different ($p < 0.05$).

Germination Category	Treatment	Avg. # Seeds		Std. Dev.	Std. Error	Min. # Seeds	Max. # Seeds
Normal Radicle ¹	Control	97.0	<i>a</i>	1.7	1.0	95	98
	Trt_A	1.3	<i>b</i>	1.5	0.9	0	3
	Trt_B	0.3	<i>b</i>	0.6	0.3	0	1
	Trt_C	0.0	<i>b</i>	0.0	0.0	0	0
	Trt_D	1.7	<i>b</i>	1.5	0.9	0	3
Abnormal Radicle ²	Control	0.3	<i>b</i>	0.6	0.3	0	1
	Trt_A	1.7	<i>a</i>	0.6	0.3	1	2
	Trt_B	0.0	<i>b</i>	0.0	0.0	0	0
	Trt_C	0.3	<i>b</i>	0.6	0.3	0	1
	Trt_D	0.0	<i>b</i>	0.0	0.0	0	0
Split Seedcoat ³	Control	0.0	<i>c</i>	0.0	0.0	0	0
	Trt_A	1.7	<i>bc</i>	2.1	1.2	0	4
	Trt_B	9.7	<i>a</i>	2.1	1.2	8	12
	Trt_C	3.0	<i>bc</i>	1.0	0.6	2	4
	Trt_D	4.0	<i>b</i>	1.0	0.6	3	5
Ungerminated ⁴	Control	2.7	<i>c</i>	2.1	1.2	1	5
	Trt_A	95.3	<i>ab</i>	3.8	2.2	91	98
	Trt_B	90.0	<i>b</i>	1.7	1.0	88	91
	Trt_C	96.7	<i>a</i>	1.5	0.9	95	98
	Trt_D	94.3	<i>ab</i>	2.5	1.5	92	97

¹ Normal Radicle = Seeds completing germination with protrusion and growth of a normal radicle (Figure 1A).

² Abnormal Radicle = Seeds completing germination with protrusion and growth of a thickened, curled, stunted radicle (Figure 1B).

³ Split Seedcoat = Seeds showing incomplete germination as evidenced by splitting of the seedcoat adjacent to the procambium and radicle, and visible swelling of those tissues, but no radicle protrusion (Figure 1C, Figure 2).

⁴ Ungerminated = Seeds showing no obvious visible signs of physiological activity.

Table 2. Average initial and post-germination test weight of 10 redroot pigweed seeds for each treatment. Within each category, means followed by the same letter are not significantly different ($p < 0.05$).

Treatment	Status	Avg. Weight of 10 Seeds (g)	Std. Dev.	Std. Error	Min. Wt.	Max. Wt.
Control ¹	Initial	0.0040	0.0002	0.0001	0.0038	0.0042
	Post
Trt_A	Initial	0.0041 <i>b</i>	0.0003	0.0001	0.0039	0.0044
	Post	0.0056 <i>a</i>	0.0004	0.0002	0.0053	0.0060
Trt_B	Initial	0.0040 <i>b</i>	0.0001	0.0001	0.0039	0.0041
	Post	0.0053 <i>a</i>	0.0002	0.0001	0.0051	0.0055
Trt_C	Initial	0.0037 <i>b</i>	0.0003	0.0002	0.0035	0.0040
	Post	0.0055 <i>a</i>	0.0004	0.0002	0.0051	0.0058
Trt_D	Initial	0.0040 <i>b</i>	0.0002	0.0001	0.0039	0.0043
	Post	0.0057 <i>a</i>	0.0003	0.0002	0.0054	0.0060

¹ There were not enough seeds left to weigh in Control petri dishes at the end of germination test.

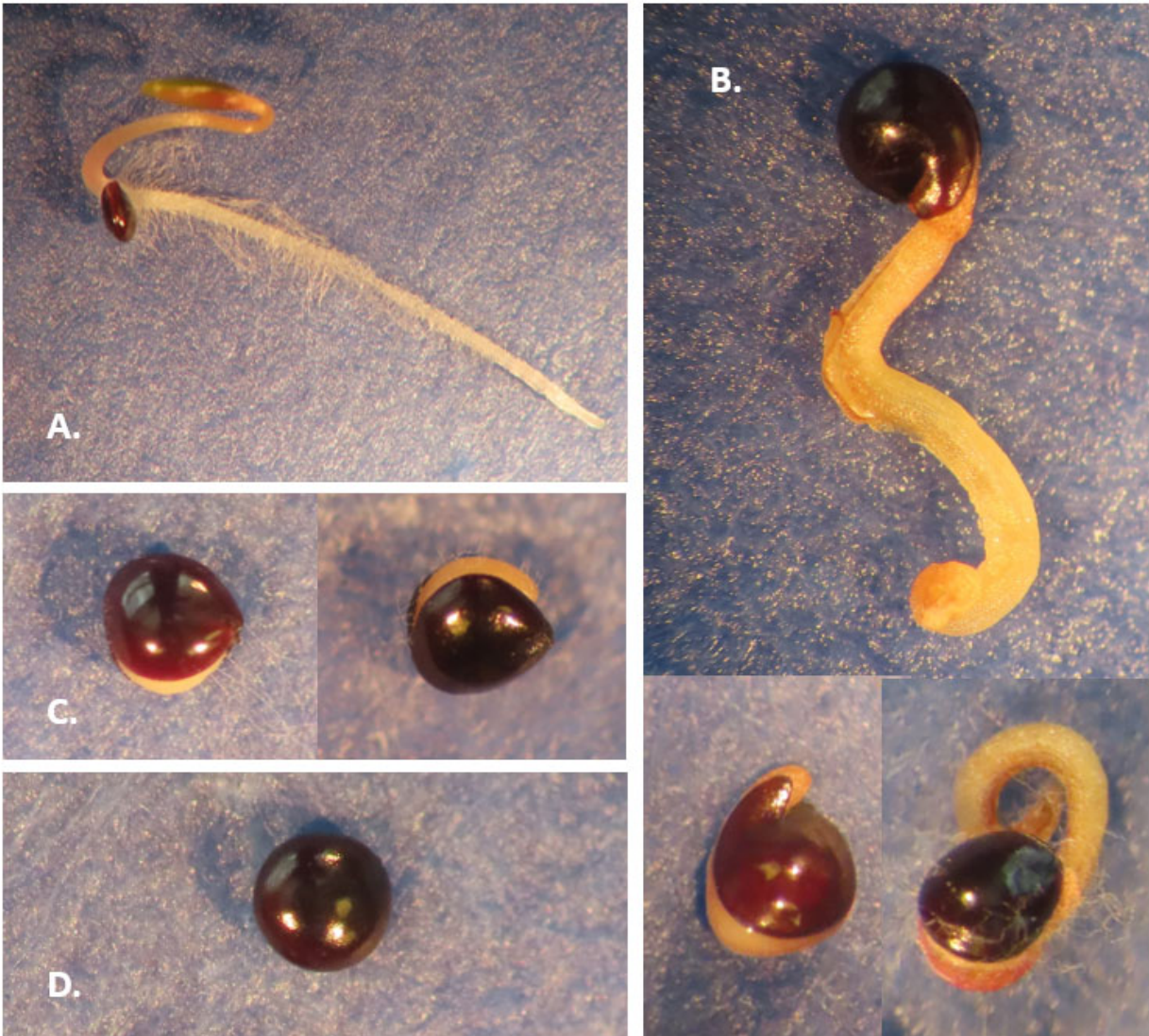


Figure 1. Examples of redroot pigweed seeds in the four germination categories: normal radicle (A), abnormal radicle (B), split seedcoat (C), and ungerminated (D).

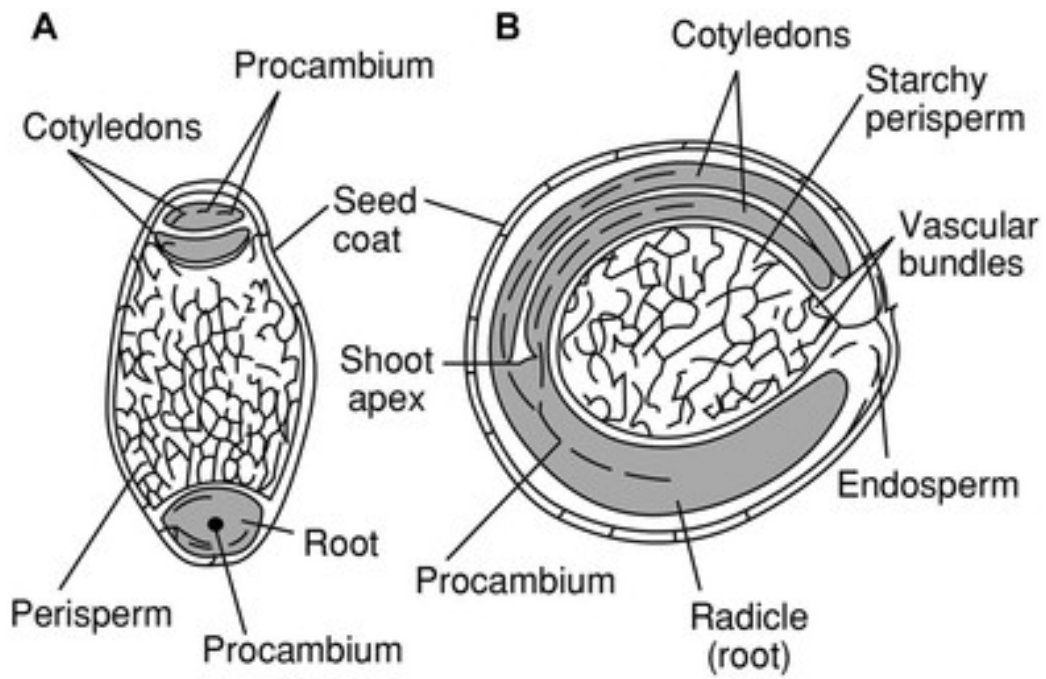


Figure 2. Amaranth seed in (A) cross- and (B) longitudinal sections as viewed in a light microscope.
Source: Irving et al. 1981.

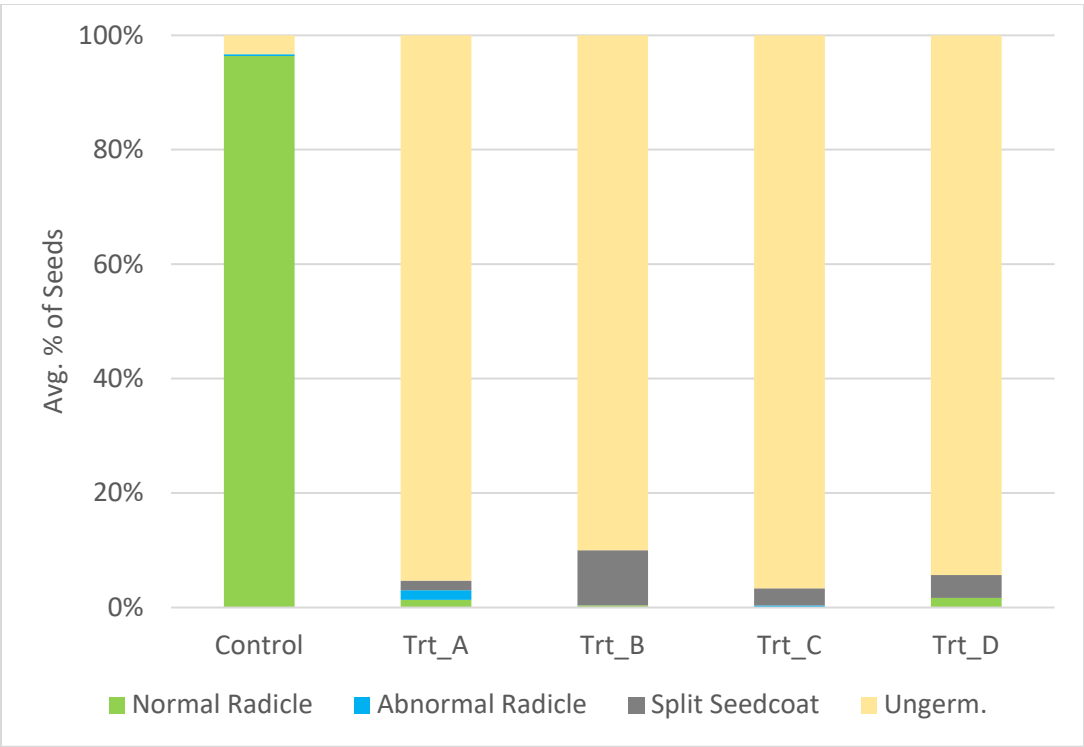


Figure 3. Average percent of redroot pigweed seeds in the four different germination categories (normal radicle, abnormal radicle, split seedcoat, and ungerminated) for the Control and Treatments A to D at the end of the germination test.

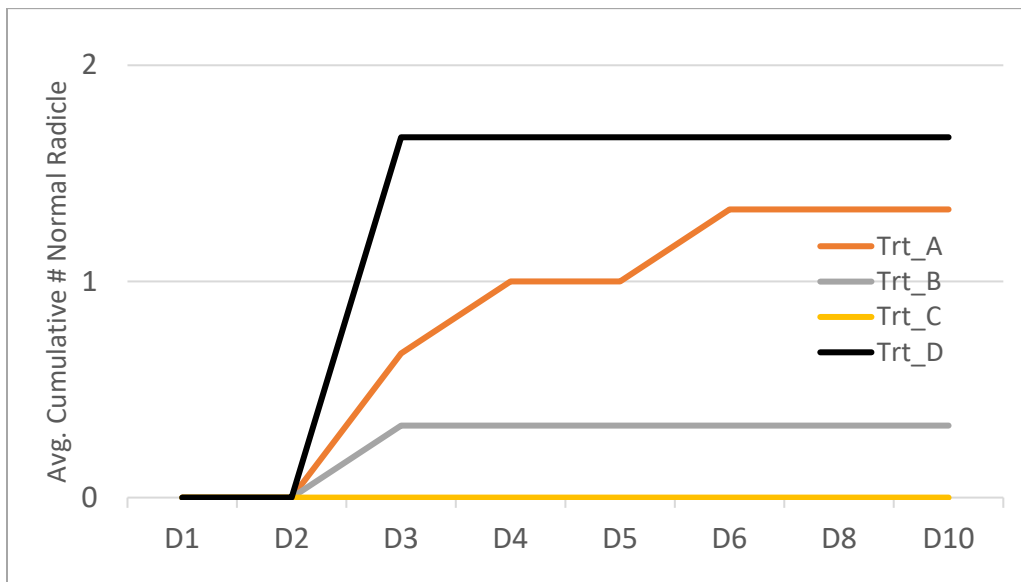
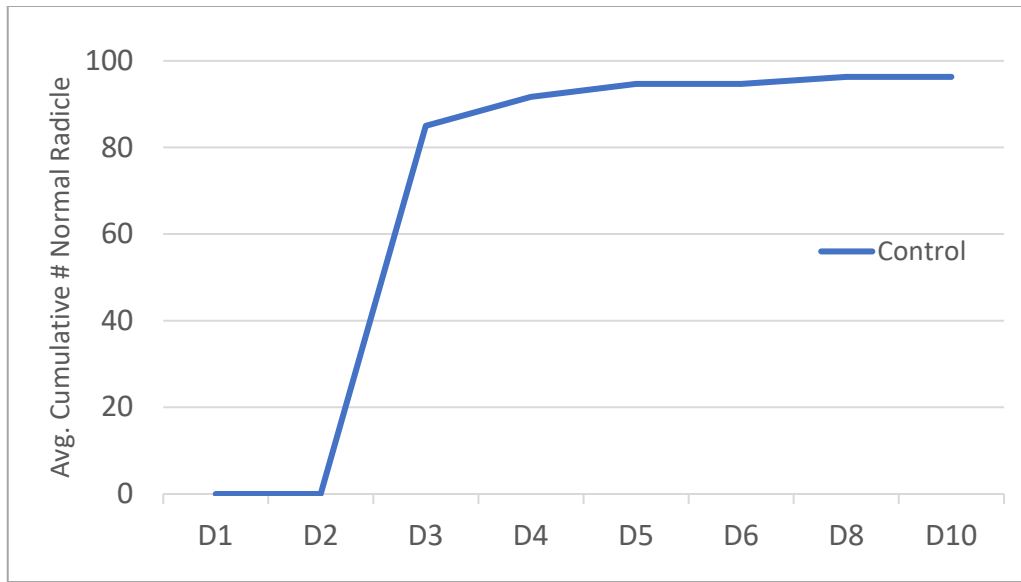


Figure 4. Cumulative number of germinated seeds with a normal radicle for the Control (top) and Treatments A to D (bottom) from Day 1 to Day 10.

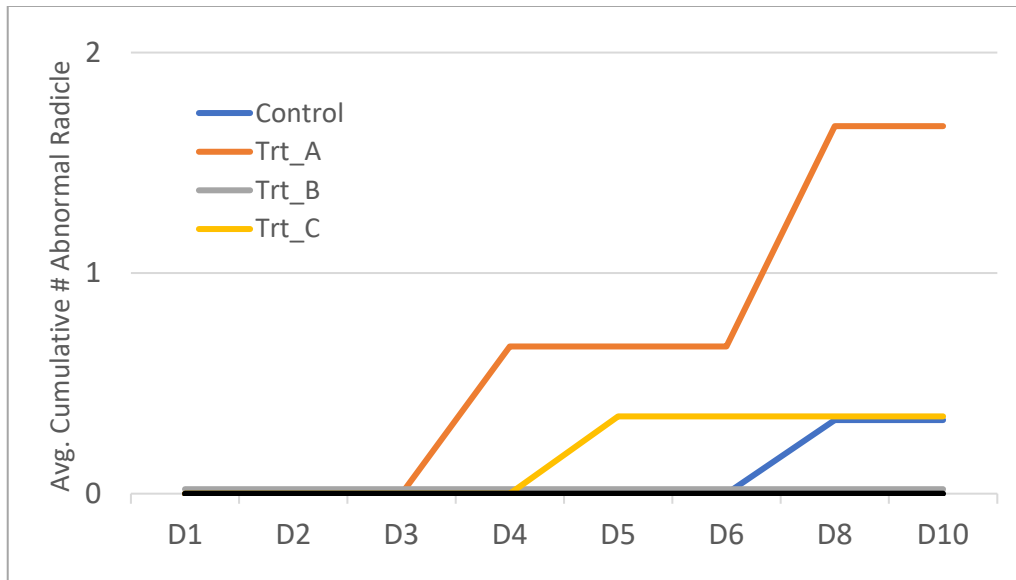


Figure 5. Cumulative number of germinated seeds with an abnormal radicle for the Control and Treatments A to D from Day 1 to Day 10.

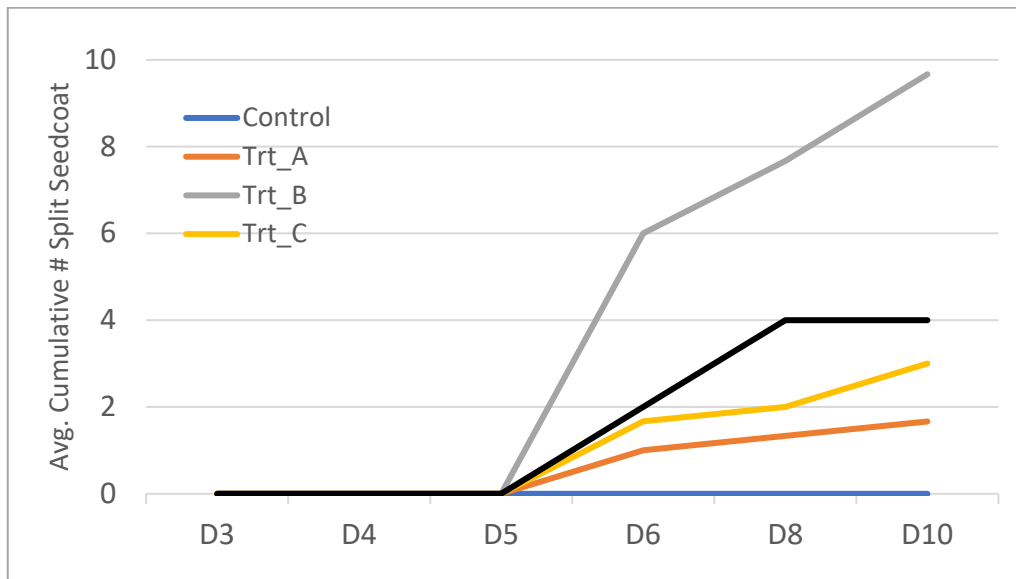


Figure 6. Cumulative number of germinated seeds with a split seedcoat for the Control and Treatments A to D from Day 5 to Day 10 (seeds with a split seedcoat were observed starting Day 4, but were not recorded until Day 6).