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What are the critical phenological periods for sustainable perennial grain production in the annual development of intermediate wheatgrass?

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Introduction: We previously suggested an annual growth cycle for perennial grasses with respect to plant development and seed productivity (1). This cycle begins after harvest of the current year's seed crop and extends through to the next seed harvest, crossing calendar years. Others have shown that environmental conditions from a previous growing season have correlations to the current years seed production potential (2). Species will be different (2,3,4,5) and therefore this will require patience as species individual needs must be determined. Intermediate wheatgrass (*Thinopyrum intermedium*) is approaching the market in North America. A first study has been published with respect to phenological development (7). Understanding the phenological development will aid in developing effective agronomic practices for sustained grain productivity.

Materials and Methods: The analysis is based upon the results of breeding nurseries and seed production experiments on intermediate wheatgrass grown in either Carman (49°50'N, 98°04'W)(nine site years) or Winnipeg, MB (49°81'N, 97°12'W)(six site years) in order to determine base T of and gdd to initiation of anthesis. Observation and results from trials in France (ISARA - Lyon, various locations) allowed for observations regarding initiation of reproductive tiller elongation (RTE), in determining a most likely day length due to an earlier onset of spring (see Table 2 for Manitoba spring dates). Means and standard deviations were used to calculate coefficients of variation for the onset of anthesis.

Results to date: Plant growth and development are impacted by growing conditions and are dominated by two measures; precipitation (ppt) and gdd (Table 1). Precipitation may have a greater influence on plant development in an IWG crop. Post-harvest regrowth (Figure 2) is important and is related to gdd and ppt. It appears that while temperature is the primary driver, as long as moisture is adequate, gdd can be adequate to set-up yield potential (reproductive tiller density). In years with short fall regrowth periods, added nutrients can aid in providing yield potential (data not shown (Figure 3)). Vernalisation is required (Figure 4). In Manitoba, spring initiation is variable (Table 2), however growth rarely is great prior to early May (days to 100 accumulated gdd base T4°C). Due to a dual induction requirement (6), a specific night-length needs to be reached for RTE (Figure 5). GDD from the beginning of RTE to first anthesis (Figure 6) appears to be in the 12 to 14 hours of daylight range (Table 3). Observations in France have indicated that RTE is most likely initiated at the 13-hour day-length (Figure 5). Therefore, timing of RTE initiation and gdd accumulation will influence agronomic practices. In Manitoba, the onset of RTE conditions generally coincides with the onset of spring (Table 2), limiting response to spring applied nutrients but providing for rapid weed competitiveness. Growth through anthesis appears to be dependent on gdd accumulation with a base temperature of 3° or 4°C. After anthesis, seed development and maturation takes place. The duration to maturity and the size of seed (Figure 7) will be dependent upon two main factors, number of seeds set inflorescence⁻¹ and climate (gdd and ppt) (Figure 8). The interaction of these factors provides the realization of seed yield at harvest (Figure 9). At this point the growth and development cycle begins anew and harvest timing and ensuing growth conditions determine inflorescence density for the following growing season. As the stand ages, nutrient status appears to increase in importance. Impacts at any stage may influence succeeding stages and therefore grain yield.

Conclusions: Reproductive tiller initiation day-length is most likely 13 hours and gdd base T is possibly 3° or 4°C (for Manitoba). This will be refined as we accumulate more data on adapted germplasm and with additional year-to-year variability. Data from other growth environments will likely provide the conclusive evidence. A gdd x precipitation interaction in the fall regrowth period in Manitoba requires a much greater volume of work to allow for resolution.



Figure 9. Grain being combined.



Figure 2. Post-harvest stand

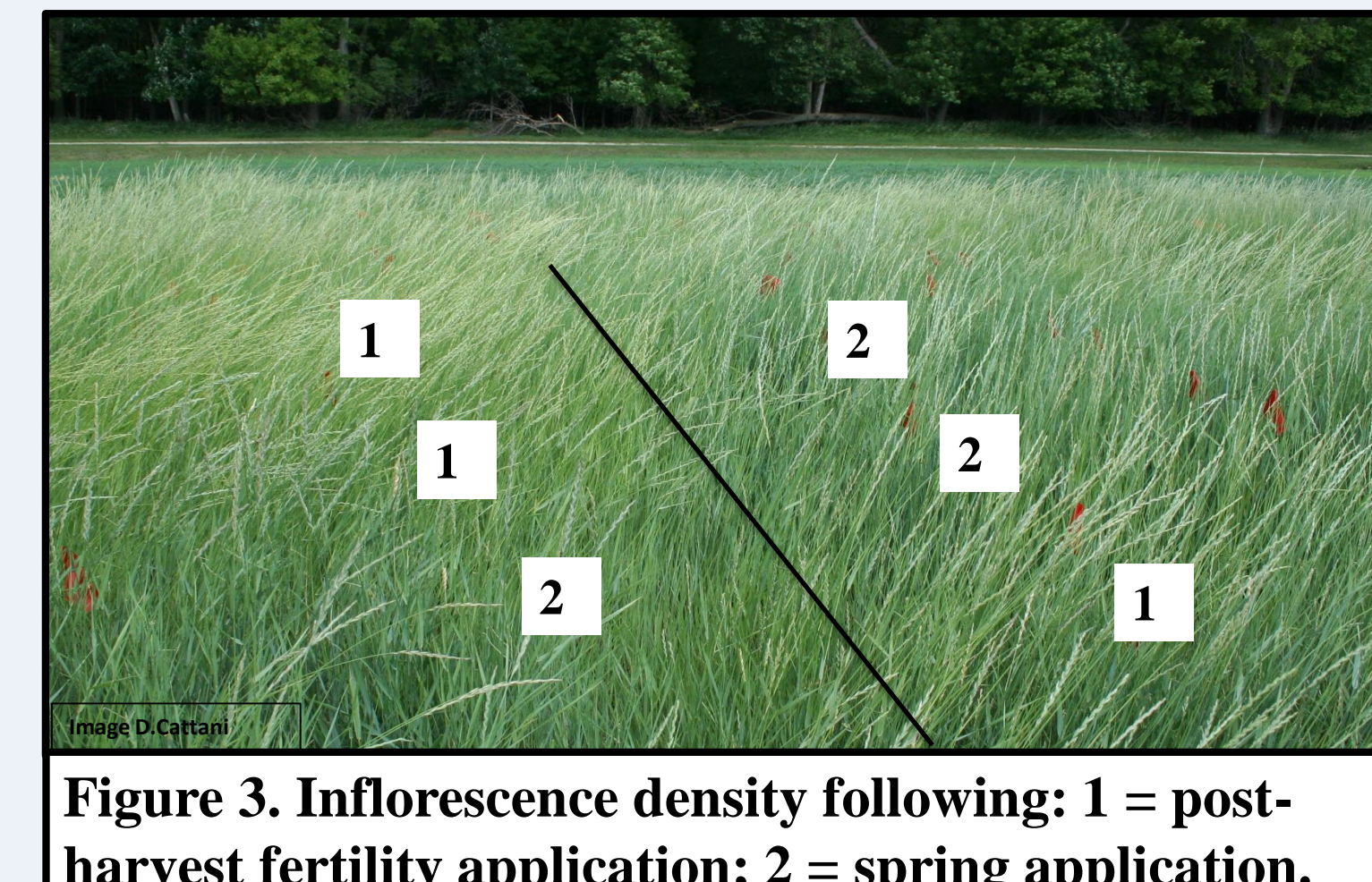


Figure 3. Inflorescence density following: 1 = post-harvest fertility application; 2 = spring application.



Figure 4: Pre-elongation of reproductive apical meristems.



Figure 8. Grain maturation in the stand.



Figure 7. Seed development within a spikelet.

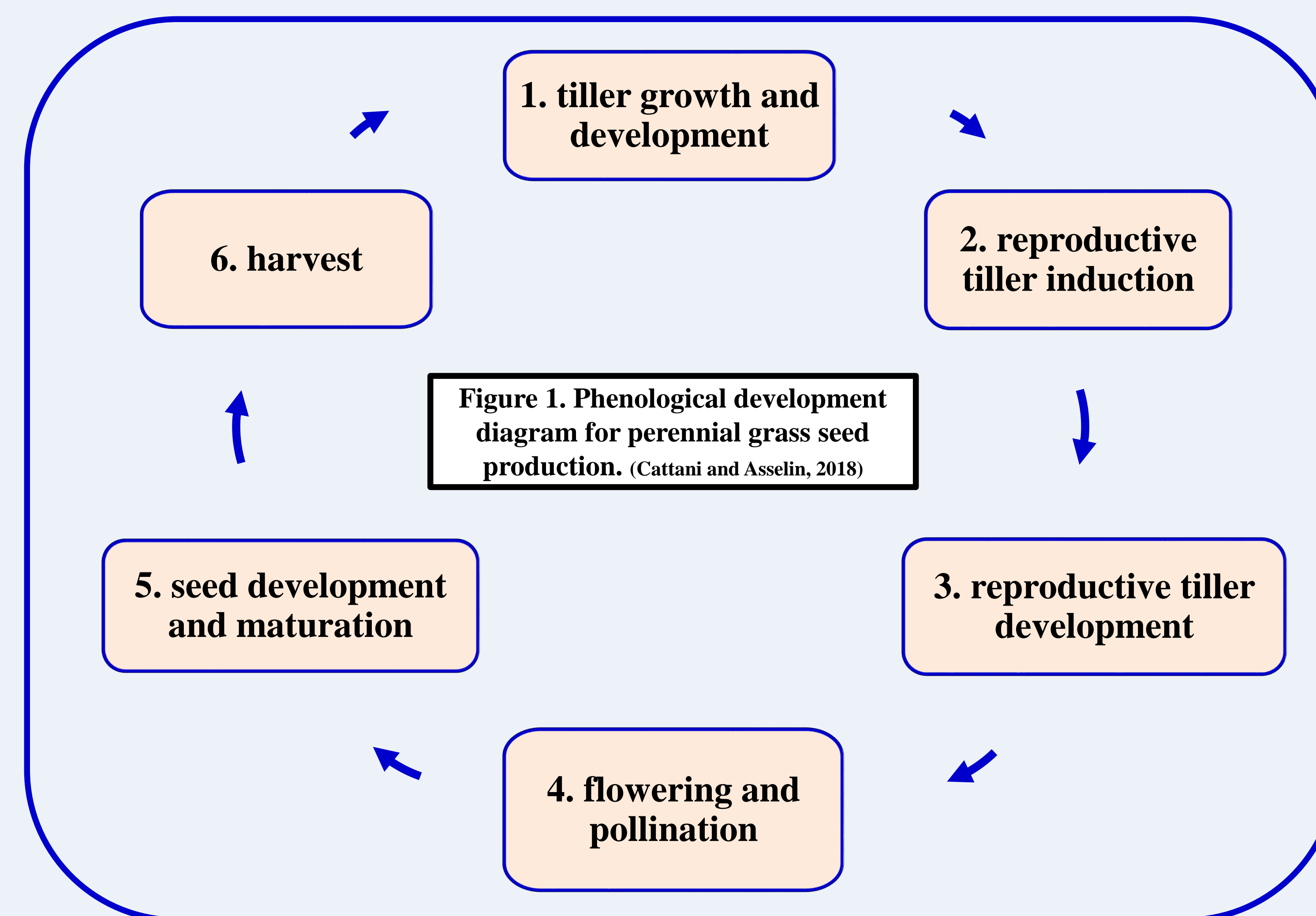


Figure 1. Phenological development diagram for perennial grass seed production. (Cattani and Asselin, 2018)

Table 1. Fall gdd and ppt and impact on harvest at Carman and Winnipeg, MB.

		Carman		Winnipeg		
year	date	gdd	ppt (mm)	harvest	yield	
2016-17	Nov 16	681	127	361	Aug 08	950
2017-18	Oct 25	709	115	357	July 31	842
2016-17	Nov 16	724	128	351	Aug 07	866
2017-18	Oct 25	715	85	242	Aug 01	387

Table 3. Selected growing degree-day analysis from Carman 2012-2019.

	vt _{d5} ¹	h ₁₂₅	h ₁₃₅	h ₁₄₅	h ₁₅₅
mean	733.60	729.21	724.35	671.40	525.74
s.d.	34.89	34.91	35.29	38.53	124.12
c.v.	4.76	4.79	4.87	5.74	23.61
	vt _{d4}	h ₁₂₄	h ₁₃₄	h ₁₄₄	h ₁₅₄
mean	810.74	804.59	797.21	736.10	571.13
s.d.	39.54	38.36	37.88	45.95	139.33
c.v.	4.88	4.77	4.75	6.24	24.40
	vt _{d3}	h ₁₂₃	h ₁₃₃	h ₁₄₃	h ₁₅₃
mean	890.79	882.68	872.18	797.35	616.80
s.d.	45.55	42.72	41.25	55.61	154.85
c.v.	5.11	4.84	4.73	6.97	25.11
	vt _{d0}	h ₁₂₀	h ₁₃₀	h ₁₄₀	h ₁₅₀
mean	1152.02	1130.55	1105.76	992.24	754.30
s.d.	78.09	67.89	61.56	89.10	201.87
c.v.	6.78	6.00	5.57	8.98	26.76

¹ vt_{d5} - year to date - 5°C based temperature, h₁₂ - 12-hour day-length accumulation, s.d. standard deviation of the mean, c.v. coefficient of variation.



Figure 6. Flowering and pollination in intermediate wheatgrass.



Figure 5: Elongated reproductive shoots.

Table 2. Beginning growing degree days (base 4°C) at Carman since 2011.

Year	First day (base 4°C)	Next day of gdd accumulation	Date of 100 gdd
2011	March 14, 2011	April 10, 2011	May 07
2012	March 12, 2012	March 14, 2012	April 15
2013	April 26, 2013	April 27, 2013	May 17
2014	April 09, 2014	April 10, 2014	May 23
2015	March 10, 2015	March 14, 2015	Apr 01
2016	Feb. 23, 2016	March 06, 2016	May 04
2017	March 29, 2017	March 30, 2017	May 04
2018	April 19, 2018	April 20, 2018	May 07
2019	April 7, 2019	April 15, 2019	May 12