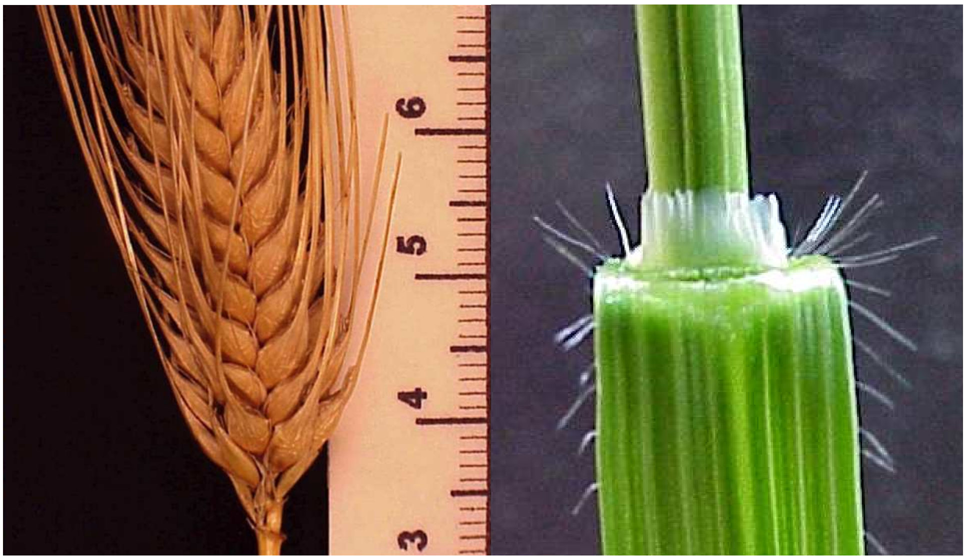
Crop Identification and BBCH Staging Manual: SMAP-12 Field Campaign



Earth Observation Research Branch Team
Agriculture and Agri-Food Canada

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Introduction:

This manual is meant to aid in the identification of crops in Manitoba, as well as characterize specific growth stages using the BBCH scale. In Manitoba some crops cover a larger area in terms of acreage, and so may be more commonly encountered. This should be taken into consideration during crop identification (Table 1).

Table 1: Percent cover of various land cover types in the two proposed study areas (Wiseman, 2011).

Study Area #1			
Land Cover Type	**Square Km**	**Square Miles**	**Percent Area**
Water	4.96	1.94	0.47
Exposed Land	0.03	0.01	0.00
Developed Land	35.73	13.96	3.40
Shrub Land	9.89	3.86	0.94
Wetland	3.66	1.43	0.35
Grassland\Pasture	172.52	67.39	16.43
Fallow	0.31	0.12	0.03
Cereals	338.40	132.19	32.23
Corn	73.28	28.62	6.98
Canola	138.63	54.15	13.20
Flax	7.41	2.90	0.71
Sunflowers	18.44	7.20	1.76
Soybeans	70.48	27.53	6.71
Pulse Crops	16.85	6.58	1.60
Potatoes	6.03	2.35	0.57
Other Crops	1.97	0.77	0.19
Coniferous Forest	0.01	0.00	0.00
Deciduous Forest	151.42	59.15	14.42
Study Area #2			
Land Cover Type	**Square Km**	**Square Miles**	**Percent Area**
Water	3.94	1.54	0.37
Exposed Land	0.82	0.32	0.08
Developed Land	41.25	16.11	3.93
Shrub Land	6.60	2.58	0.63
Wetland	4.28	1.67	0.41
Grassland\Pasture	87.51	34.18	8.33
Cereals	359.17	140.30	34.19
Corn	80.49	31.44	7.66
Canola	251.93	98.41	23.98
Flax	8.61	3.36	0.82
Sunflowers	13.52	5.28	1.29
Soybeans	41.30	16.13	3.93
Pulse Crops	46.42	18.13	4.42
Potatoes	13.89	5.43	1.32
Other Crops	0.62	0.24	0.06
Coniferous Forest	0.06	0.02	0.01
Deciduous Forest	90.16	35.22	8.58

1.0. Cereals/Small Grains

1.1. General

Common cereals include wheat (including spring and winter), oats, barley and rye. These flowering plants are structured similarly because they are part of the grass family (Figure 1). Grasses are typified by leaf blades that are alternating, sheathed and jointed by nodes. The first stem that develops may be considered the main or parent shoot. Through the process of *tillering* many secondary stems or branches also develop. They can form at the base on the plant (crown), or through underground stems (rhizomes) and above ground roots (stolons) (Barnhart, 1999). In an agricultural setting most plants will have two to four tillers, though this is dependent upon seeding practices and environmental conditions. Seedheads or inflorescences form on the top of all main stems and in most cases on two to four tillers as well (Strand et al., 1990).

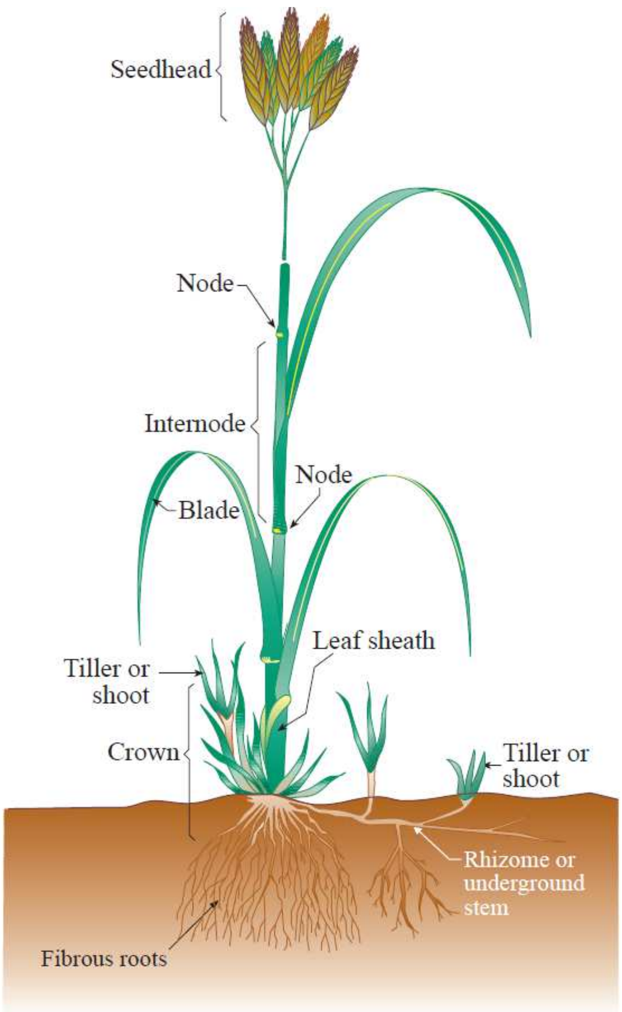


Figure 1: General morphology of cereal plants (Barnhart, 1999).

1.2. Identifying Growth Stages: BBCH Scale

The following will provide a description of the main stages of development for cereals, based on the BBCH scale (Table 2). This can be used to identify the main stages of development for wheat (including spring and winter), oats, barley and rye. In most cases it may also be appropriate to use this scale to identify the growth stages for grasses such as Timothy.

Table 2: BBCH growth stages for cereals including barley, oats, wheat, and rye.

0. Sprouting/Germination	
00	Dry seed (caryopsis)
01	Beginning of seed imbibition
03	Seed imbibition complete
05	Radicle emerged from caryopsis
06	Radicle elongated, root hairs/side roots visible
07	Coleoptile emerged from caryopsis
09	Coleoptile penetrates soil
1. Leaf Development	
10	First leaf through coleoptile
11	First leaf unfolded
12	2 leaves unfolded
13	3 leaves unfolded
1…	Stages continuous till …
19	9 or more leaves unfolded
2.Tillering	
20	No tillers
21	First tiller detectable
22	2 tillers detectable
23	3 tillers detectable
2…	Stages continuous till ….
29	Max no. of tillers detectable
3. Stem Elongation	
30	Pseudostem & tillers erect, first internode elongating, top of inflorescence at least 1 cm above tillering node
31	First node at least 1 cm above tillering node
32	Node 2 at least 2 cm above node 1
33	Node 3 at least 2 cm above node 2
3…	Stages continuous till …
37	Flag leaf just visible, rolled (last leaf)
39	Flag leaf unrolled, ligule just visible
4. Booting	
41	Early boot: flag leaf sheath extending
43	Mid boot: flag leaf sheath just visibly swollen
45	Late boot: flag leaf sheath swollen
47	Flag leaf sheath opening
49	First awns visible (in awned forms only)

5. Inflorescence Emergence, Heading	
51	Tip of inflorescence emerged from sheath, first spikelet just visible
52-54	20% to 40% of inflorescence emerged
55	Half inflorescence emerged
56-58	60% to 80% inflorescence emerged
59	Inflorescence fully emerged
6. Flowering, Anthesis	
61	First anthers visible
65	Full flowering: 50% of anthers mature
69	End of flowering: all spikelets flowered some dry anthers may remain
7: Development of Fruit	
71	Watery ripe: first grains half final size
73	Early milk
75	Medium milk: grain content milky, Grains final size, still green
77	Late milk
8. Ripening	
83	Early dough
85	Soft dough: grain content soft but dry. Fingernail impression not held
87	Hard dough: grain content solid Fingernail impression held
89	Fully ripe: grain hard difficult to divide with thumbnail
9. Senescence	
92	Over-ripe: grain very hard, cannot be dented by thumbnail
93	Grains loosening in day-time
97	Plant dead & collapsing
99	Harvested product

From Sprouting to Heading:

Figure 2 represents an illustration from emergence to heading representing the general growth pattern for cereals.

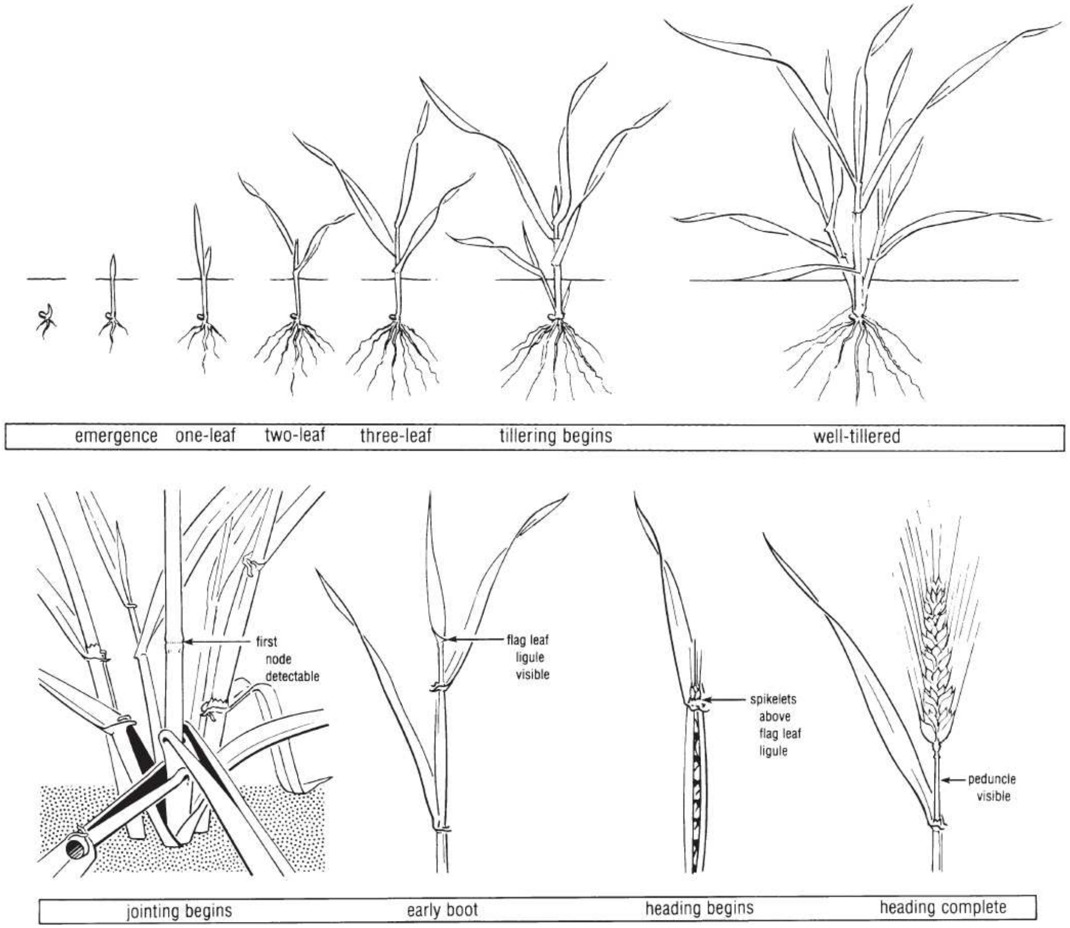


Figure 2: Illustration representing the general growth pattern of a cereal plant from emergence to heading. (Barnhart, 1999)

0. Sprouting/Germination

For most applications it is not important to identify stages 00 to 08, as these occur when the plant is below the soil surface. At stage 09 the coleoptile penetrates the soil. It is a rigid feature of the plant that contains the tissue of the first leaves (Strand et al., 1990).

1. Leaf Development

Following penetration of the surface by the coleoptile (sprouting), the first leaf of the plant emerges. Figure 3 shows examples where: a) the first leaf has just broken through the coleoptile, and b) where the first leaf has started to unroll. In both cases the plant is identified as BBCH: 10, since the leaf has not completely unfolded and so cannot be counted. Remember that it is important to count any dead or missing leaves, so check the main stem of the plant (Strand et al., 1990)

a) b) c) d)

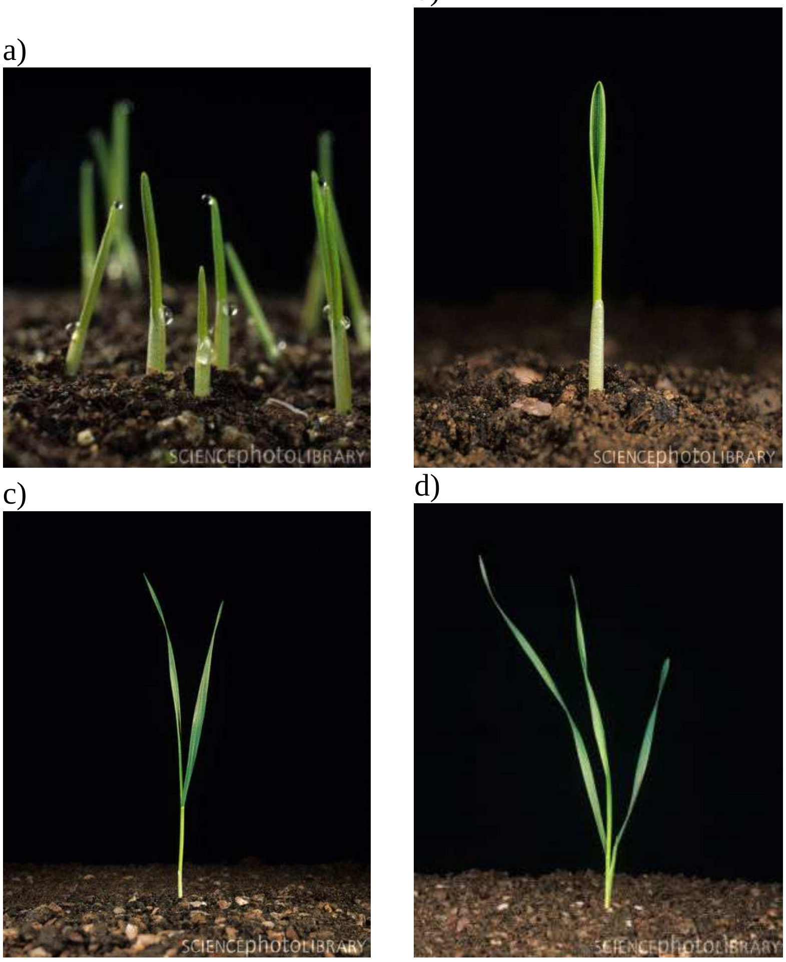


Figure 3: Emerging wheat plants at BBCH: 10 (a), late BBCH: 10 (b), BBCH: 11 (c) and BBCH 13 (d) (Science Photo, 2012a; Science Photo, 2012b; Science Photo, 2012c; Science Photo, 2012d).

2. Tillering

Development of primary tillers usually begins when the fourth leaf emerges from the stem, followed by the second primary tiller when the fifth leaf emerges… This process continues until two to four primary tillers have developed (Strand et al., 1990). It is likely the inflorescences will develop on these tillers (i.e. ones that develop during fourth, fifth and sixth leaf stage), where those that develop later may be aborted (Simmons et al., 1995).

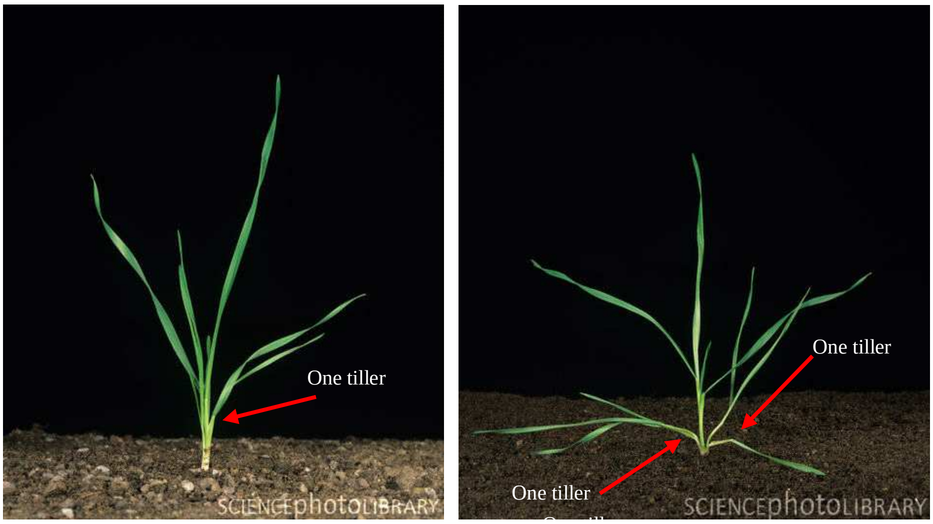


Figure 4: Photo of a wheat plant at BBCH: 21 (left) and BBCH: 22 (right) (Science Photo, 2012e; Science Photo, 2012f).

The structure of tillers is similar to the main stem, but these can be differentiated based on the fact that tillers typically have fewer leaves, and are shorter (Strand et al., 1990). When counting tillers it is important to remember some may have broken off or died. This can be especially problematic in mature plants, where tillers that do not develop an inflorescence can be aborted by the plant. In most cases you should only count primary tillers that form at the crown, as opposed to secondary and tertiary tillers that develop off of primary and secondary tillers, respectively (Larsen et al., 2012).

Throughout tillering the seed heads or inflorescence start to develop in both tillers and the main stem. Initially the head is microscopic in size, but when the head is completely formed the plant will move in to stem elongation or jointing. At that time most plants will have five fully developed leaves (Strand et al., 1990; Simmons et al., 1995; Larsen et al., 2012).

3. Stem Elongation

Again, by the time stem elongation begins plants typically have five fully developed leaves. Stem elongation is the process by which internodes lengthen in both the main stem and tillers. This process starts with the upper five or six internodes, which brings nodes above the soil surface. These joints are harder, larger in diameter than the main stem or internodes and solid, compared to the hollow inter-node in most cases. Only count the nodes on the main stem. You can usually see or feel these by hand. If you cannot detect any nodes, the stem can be split lengthwise (Figure 5) to see if any have been brought above the soil surface (Strand et al., 1990, Larsen et al., 2012).

Figure 5: Photo of a wheat plant being dissected down the middle to see if any nodes have been brought above the soil surface.

BBCH: 30

The developing inflorescence should be visible when you split the plant down the Middle (Figure 6). The plant is at stage BBCH: 30, when the tip of the tip of the inflorescence is 1cm or more above the tillering node.

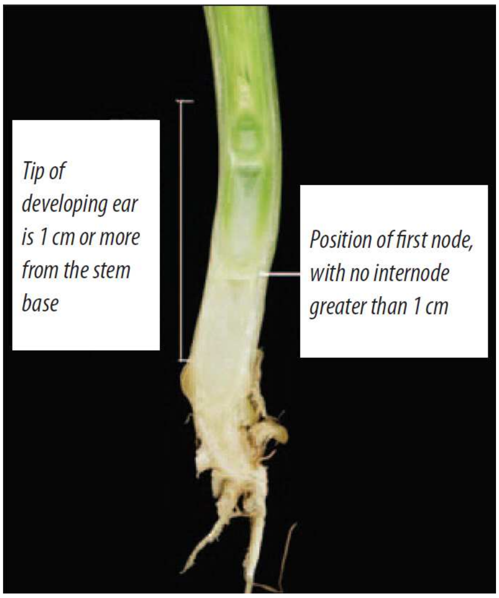


Figure 6: Photo of a wheat plant at BBCH: 30, the beginning of stem elongation (Pool et al., 2006).

BBCH: 31

At BBCH: 31 the first node is at least 1 cm above the tillering node (Figure 7, left). At BBCH: 32 node two is at least 2 cm above node one (Figure 13).

Figure 7: Photo of a wheat plant at early stage BBCH: 31 (left), and late stage BBCH: 31 (right) with two internodes detected above the soil surface, without the second being more than 2cm above the first (Pool et al., 2006).

BBCH: 32

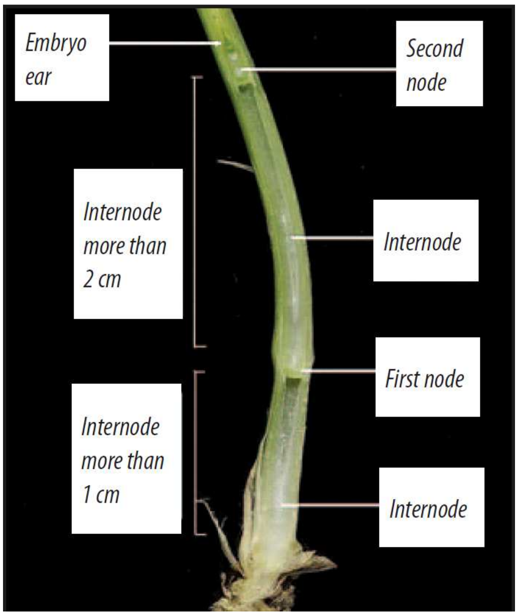


Figure 8: Photo of a wheat plant at BBCH: 32 with the second internode more than 2cm above the first (Pool et al., 2006).

BBCH: 37 & 39

At BBCH: 37 the flag leaf should be detected at the top of the main stem. This is the last leaf to develop and it usually emerges when at least three nodes are above the soil surface. Inside the flag leaf is the developing inflorescence or seedhead. When this leaf is unrolled the plant is at the end of the stem elongation stage of development and moves into booting. You can test whether the flag leaf has emerged by splitting the top internode down the middle. If there is an inflorescence inside, but no other leaves around it, then the flag leaf has emerged.

4. Booting

At the beginning of booting the flag leaf starts extending (BBCH: 41). When the flag leaf starts to swell, BBCH: 43 is reached. BBCH: 47 occurs when the leaf sheath starts to open, exposing the inflorescence within. Finally the booting stage ends when the awns are visible (in awned varieties) at the top of the boot (Figure 9).

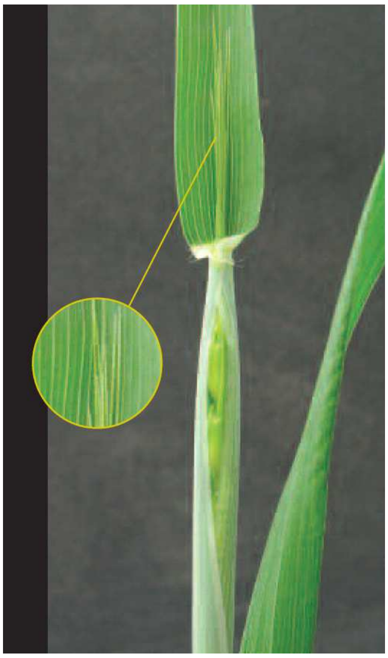


Figure 9: Photo of a wheat plant at late stage booting (BBCH: 49) where the inflorescence (Pool et al., 2006).

5. Inflorescence Emergence, Heading

Heading is the process whereby the seed head emerges from the sheath of the flag leaf, which once contained it. For both wheat and barley the shape of type of head or inflorescence is a spikelet. For oats, the inflorescence is known as a panicle. It should be noted that generally heading occurs a few days later in tillers (Strand et al., 1990). At BBCH: 55 about half of the inflorescence should be visible, or emerged from the flag leaf sheath (Figure 10). In order to see how much of the inflorescence has emerged it will be necessary to split the flag leaf sheath.

Figure 10: Photo of a wheat at BBCH: 55 where half of the inflorescence has emerged from the flag leaf sheath.

6. Flowering/Anthesis

Flowering begins only a few days (2-4) after the inflorescence has emerged unless it is very hot, which causes the heads to remain in the boot at the time of flowering (Strand et al., 1990). In most cases it is possible to identify flowering by presence of the anthers. A few anthers on the plant represent the beginning of flowering BBCH: 60, where at BBCH: 65 the entire inflorescence should contain anthers. Anthers are used to hold the plants pollen.

Figure 11: Photo of a wheat plant at about BBCH: 63 where only a portion of anthers are exposed (left) and of a wheat plant that has recently emerged from the boot without any anthers (Gavloski, 2008).

7. Development of Fruit

In the early milk stage (BBCH: 73) grains are still be green, and you should be able to squeeze a clear liquid from kernels. Into the late milk stage (BBCH: 77) this liquid will become a milky colour and will also appear thicker (Figure 12).

8. Ripening

As kernels continue to develop they reach the soft dough stage (BBCH: 85). If you press your fingernail against a kernel the impression will not hold. It is possible to differentiate plants into the hard dough stage (BBCH: 87) because impressions you make with your fingernail will be held. Finally when fully ripe (BBCH: 89) it will be difficult to make any impression into kernels.

Figure 12: Photo of wheat grains through ripening stage of late milk (BBCH: 77), soft dough (BBCH: 85), hard dough (BBCH: 87), hard kernel (BBCH: 89), and harvest ripe (BBCH: 92), from top to bottom (Flint, 1990).

9. Senescence

When a crop is harvest ripe, you will not be able to dent kernels at all (BBCH: 92).

1.3. Differentiating Cereals

During the vegetative stage of plant development features at the collar (where blades attach to the stem at the top of the leaf sheath) can be used to differentiate cereal types (Figure 13). These features include (DPI, 2006):

a) *Auricles*: Features located at the top of the leaf sheath, at the end of the blade. For certain species can be hairy, smooth, large, small or completely absent.

b) *Blades*: Leaf blades are twisted clockwise or anti-clockwise when viewed from above, depending on the species type.

c) *Ligules*: The ligule is the collar or projection that wraps around the stem and lies between the leaf sheath and stem.

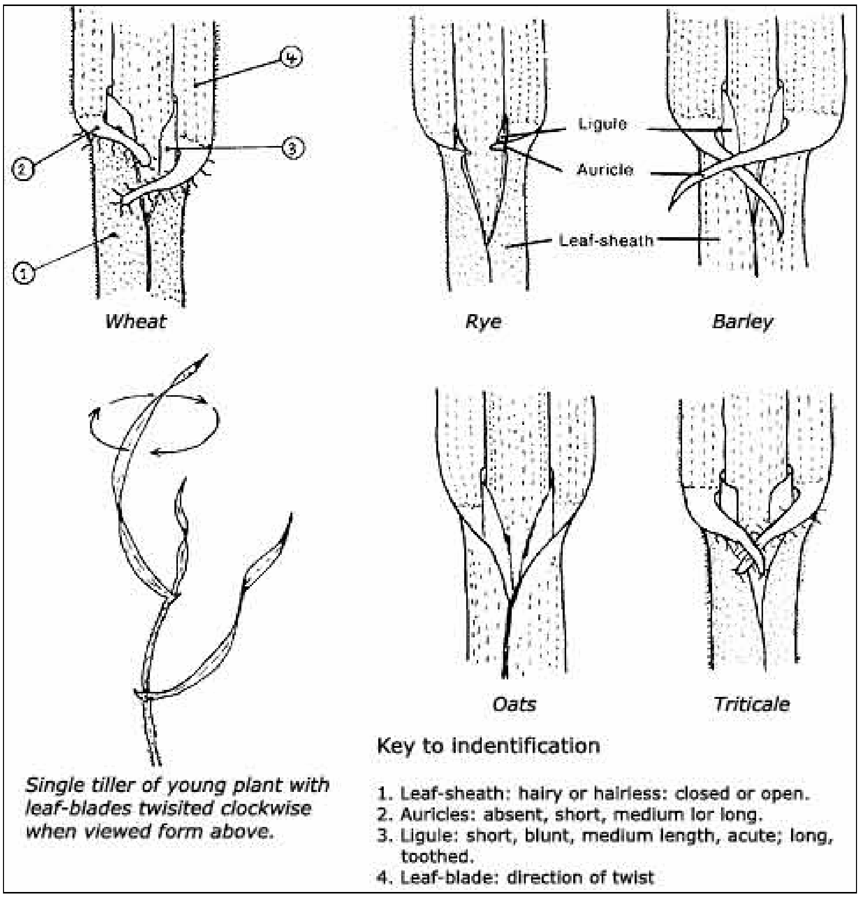


Figure 13: Illustration of the distinguishing features used to identify cereals at the vegetative stage, including auricles, blades and ligules (DPI, 2006).

The following will summarize the morphology of auricles, blades and ligules for common cereals found in Manitoba (DPI, 2006).

***Barley*:** Hairless, long, clasping auricles that wrap around stem (Figure 14). Typically hairless blades and sheath (sparse on some varieties). Very small ligule. Blades twist clockwise.

Figure 14: Photos of hairless ligule and auricles of a barley plant (left: Flickr, 2012a; right: OKU, 2012)

***Oats*:** No Auricles. Hairless blade and sheath (sparse on some varieties). Intermediate length ligule. Anti-clockwise twisting blades.

Figure 15: Photos of oat ligule and collar region without auricles (left: Flickr, 2012b; right: OKU, 2012)

Rye: Pointy, short and hairless auricles. Hairiness on blades and sheaths variable. Short ligule. Clockwise twisting blades.

Figure 16: Photos of rye plants to show ligule and auricles, as well as hairiness on stem (left: NWCB, 2010; right: OKU, 2012).

***Wheat*:** Hairy, short, slender and clasping auricles. Blades and sheaths always hairy. Intermediate to long length ligule. Clockwise twisting blades.

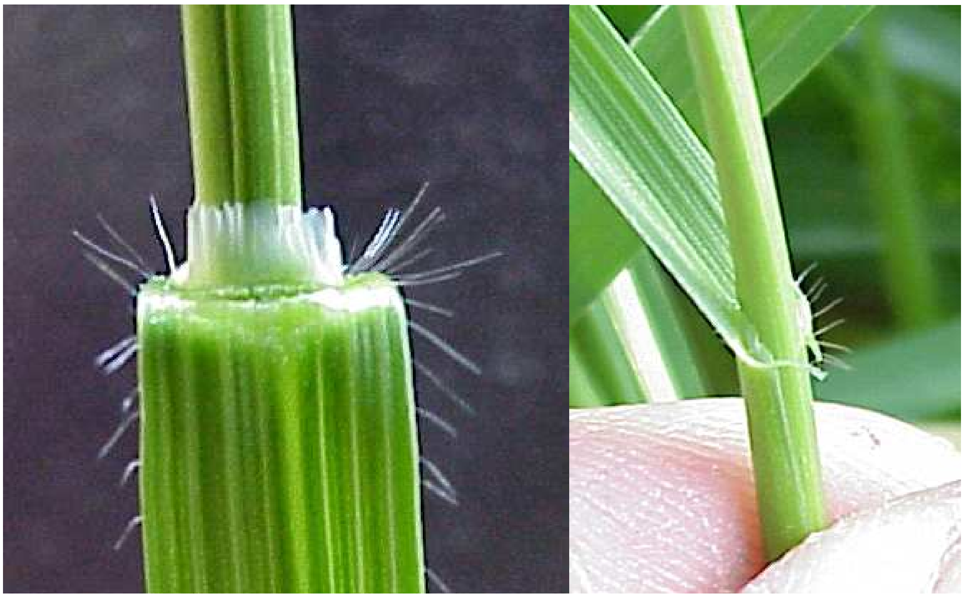


Figure 17: Photo of wheat plant to show ligule and hairy, clasping auricles (OKU, 2012).

During the reproductive stage of development defining features about the plants inflorescence can be used to discriminate cereals. The inflorescences of wheat, barley and rye are called spikelets (Figure 18), with each spikelet containing multiple florets or flowers that attach along nodes on the panicle or spike. The inflorescence of an oat pant is called a panicle, since it is composed of a number of branches, to which multiple spikelets are attached. The defining features of inflorescence which can be used to differentiate cereals include (OS, 2011):

a) *Spikelets*: contain one or more florets or flowers and form along nodes in the panicle.

a) *Glumes*: Modified leaves at the base of the spikelet.

b) *Floret*: Flower plus the internal bracts (palea) and external bracts (lemma).

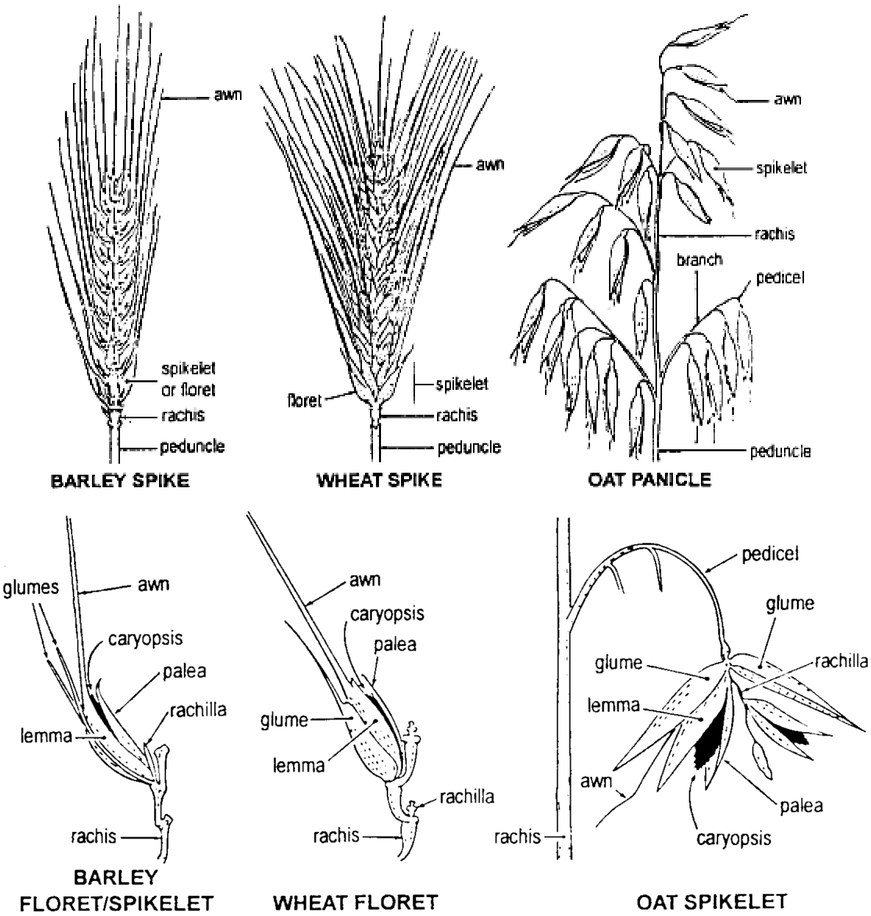


Figure 18: Inflorescence for various cereals including barley, wheat and oats (Flint, 1990).

The following will summarize the morphology of cereal grain inflorescences for the major cereals found in Manitoba (OS, 2011).

Barley: Inflorescence are spiked (Figure 19) and for each lemma there is one extending, straight awn attached at the tip. Awns can feel rough or smooth to the touch. Spikelets are stacked, one on top of the other, contain single seeds. At each node along the panicle three spikelets form (OSU, 2011).

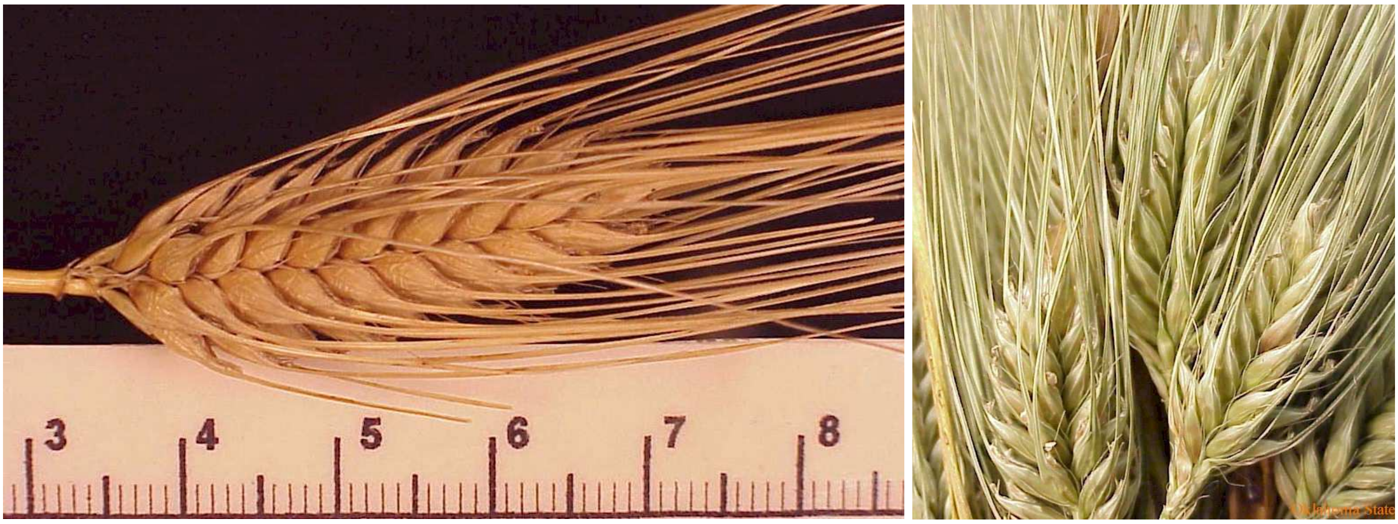


Figure 19: Photos of spiked inflorescence of barley plants (OSU, 2011).

Oats: Plants have a panicle inflorescence that attaches to the central axis via branches (Figure 20). The large paper-like covers are the plants' glumes, which contain two to three florets (Figure 20, right). One spikelet forms at the ends of branches (OSU, 2011).

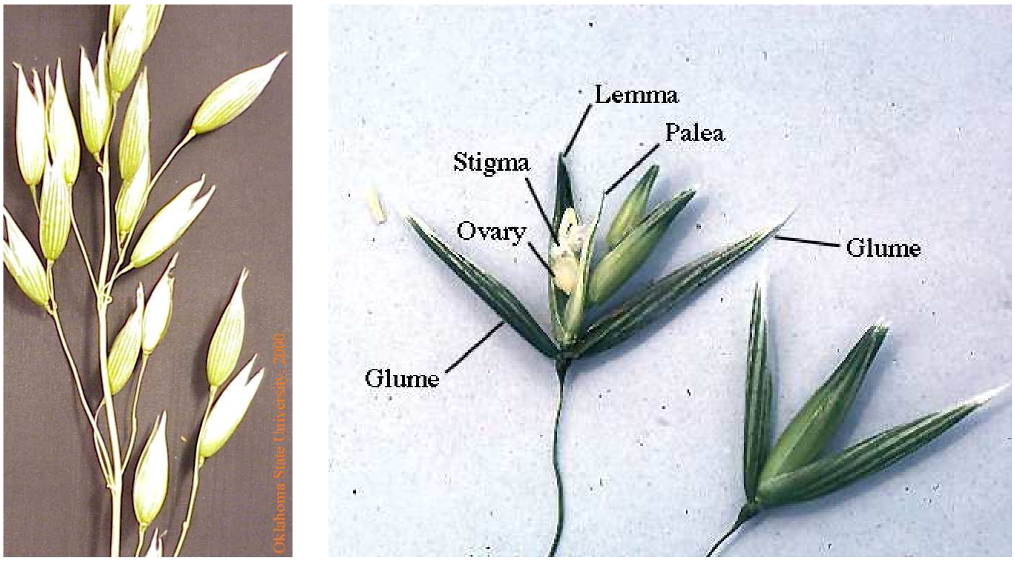


Figure 20: left (OSU, 2011), http://btny.agriculture.purdue.edu/slideviewer/slides.cfm?sequence=/slidesets/Poaceae/Poaceae.txt&slide=5&thumbs=0 (right)

Rye: Inflorescences are also spiked, though generally thinner and longer compared to other cereals like wheat (Figure 21). Rye plants are also taller than wheat (Figure 21, right). Awns are brittle, thin, long and straight. On the edges of lemma are hairs that are small and stiff, and sometimes seeds can be seen protruding from lemma (OSU, 2012).

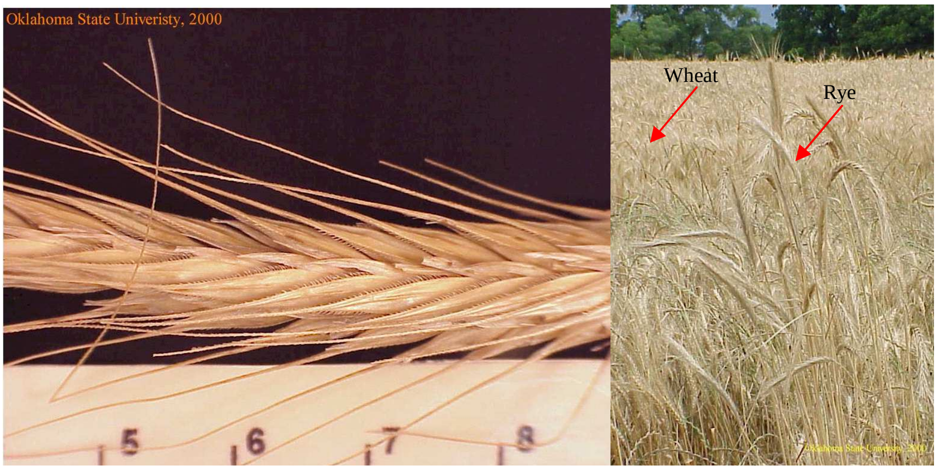


Figure 21: Photo of rye plant inflorescence (left), and rye plants in wheat field to show height differences (right) (OS, 2011).

Wheat: Spikelets are not stacked as with barley, but attach on alternating sides (Figure 22). Possible to have single or up to seven florets bunched together (Figure 22). Paleas, lemmas, and glumes are large, and all seeds are wrapped with one lemma and one palea. Where awns and lemmas for rye and barely are near parallel to the central axis of the inflorescence, those for wheat protrude out at about 45°. When harvest ripe lemma, palea and glumes can be red to white. Some varieties of wheat are also awnless, but all barley varieties have awns. At each node on the panicle one spikelet forms, which is again made up of multiple florets (three to six) (OSU, 2012).

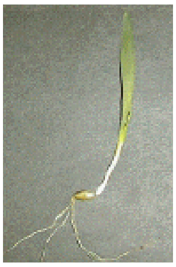
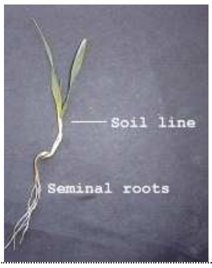
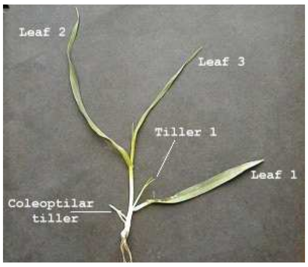
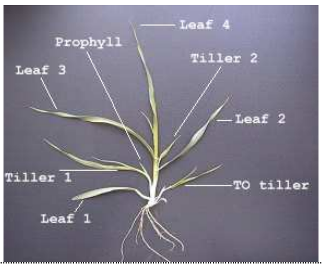
Figure 22: Photo of the alternating spikelets that make up the inflorescence of a wheat plant (left) and the three florets that make up a single spikelet for certain varieties (right). (OS, 2011).

1.1. Barley

1.1.1. General

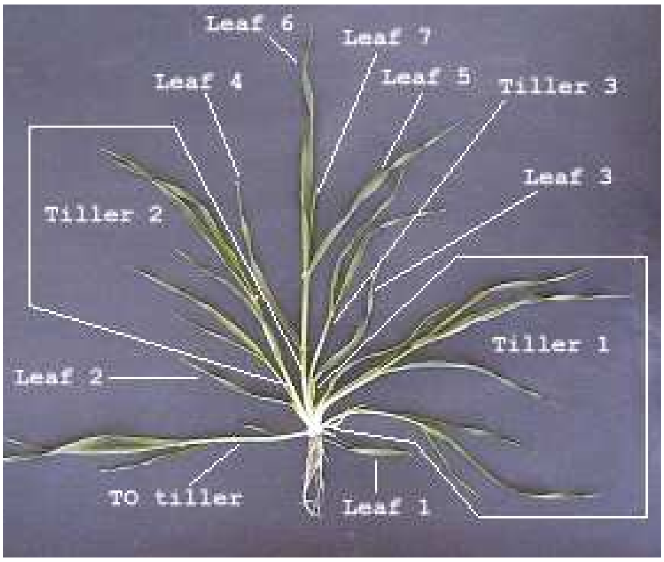
In Manitoba barley is typically planted between May 1st and May 31st and is harvested from August to October. Plant density is typically 22-25 plants/ft^2 (MAFRI, 2011).

1.1.2. Example Growth Timeline (UIE, 2012)

Growth Stage	Individual Plants	Photos of Fields
1. Leaf Development	11. 	11. 
	12.  	12. 
2. Tillering	21.  	21. 
	22.  	22. 

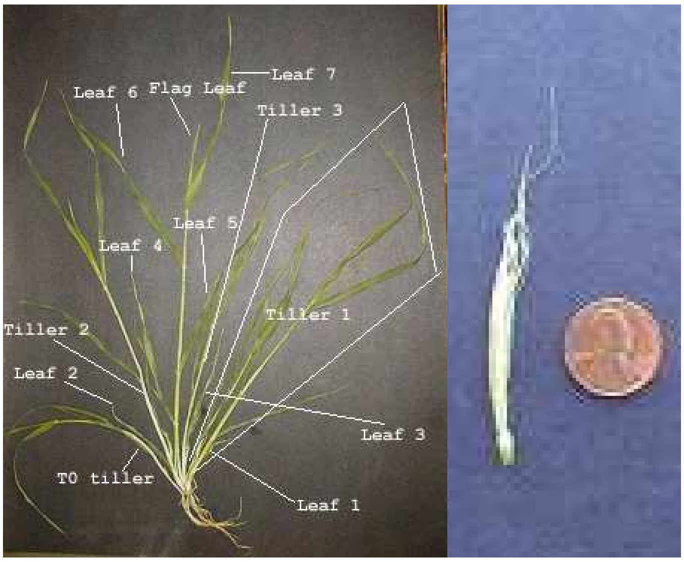
3. Stem Elongation

31.



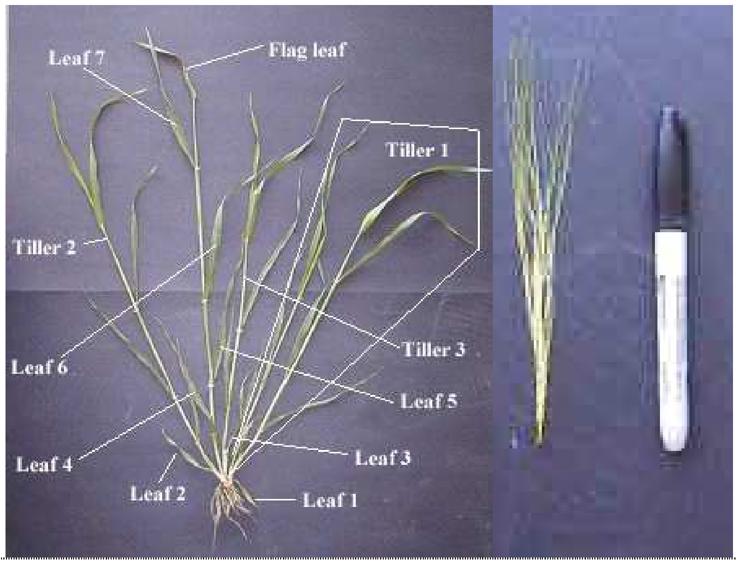
31.

37.



37.

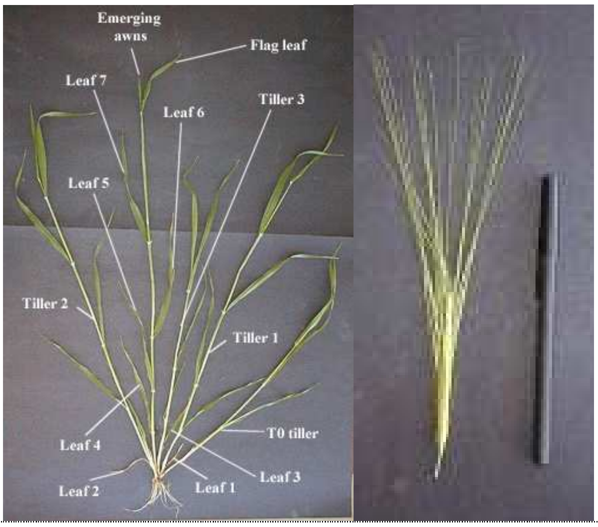
39.



39.

4. Booting

49.



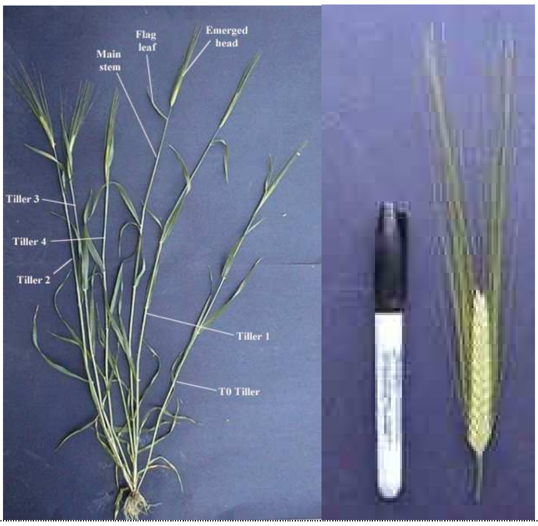
49.

6. Flowering/Anthesis

65.

65.

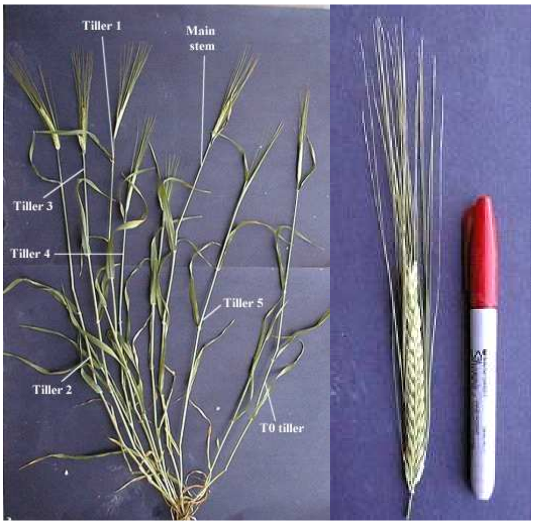
69.



69.

8. Ripening

83.



83.

85.

85.

87.

87.

9. Senescence

91.

91.

92.

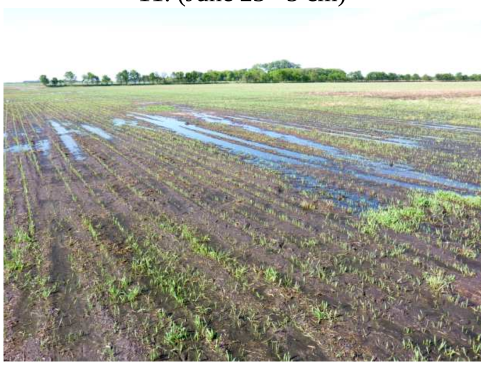
92.

1.2. Oats

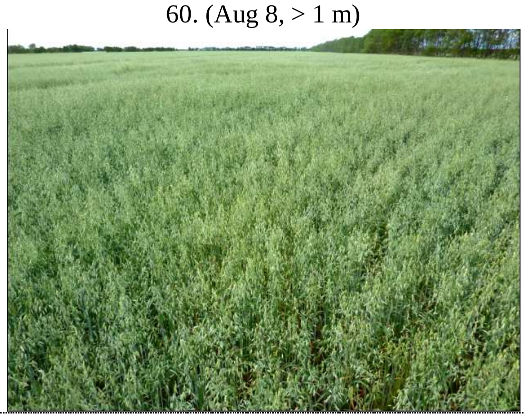
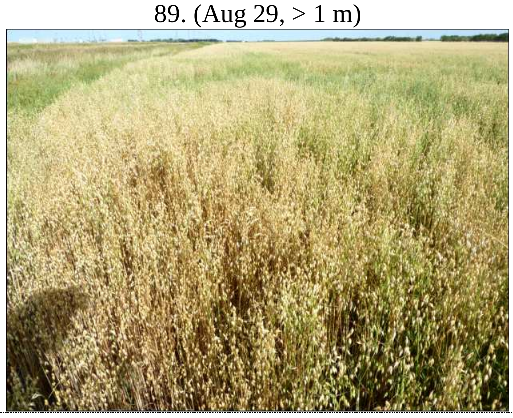
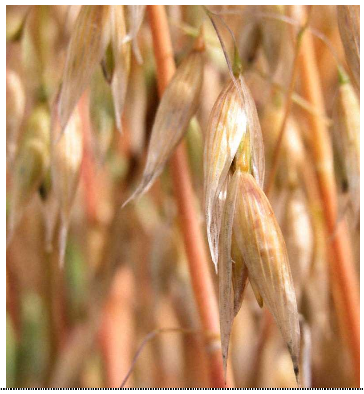
1.2.1. General

In Manitoba oats are planted between May 1^{st} and June 10^{th} and are harvested between August and October. Plant density is typically 18-23 plants/ft^2 (MAFRI, 2011). In 2009 and 2010 243 and 283 thousand hectares were seeded with oats (STATCAN, 2011).

1.2.3. Example Growth Timeline

Growth Stage	Photos of Plants Unless otherwise indicated (UKA, 2012)	Photos of Fields Unless otherwise indicated (AAFC, 2012)
1. Leaf Development	11.  (OSU, 2012) 13. 	11. (June 23^{rd} 5 cm)  13.  (UKA, 2012)

2. Tillering	21.  23. 	21. (June 2^{nd} 15 cm)  23. (July 12^{th} 16-30 cm) 
3. Stem Elongation	32.  35. 	32. (July 12^{th} 16-30 cm)  35. (July 26, 51-100 cm) 

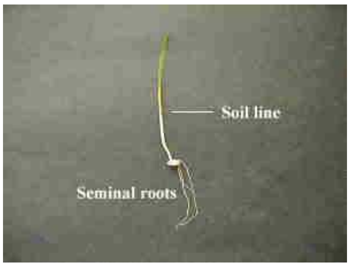
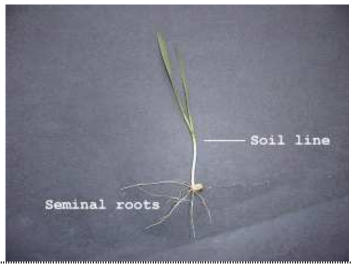
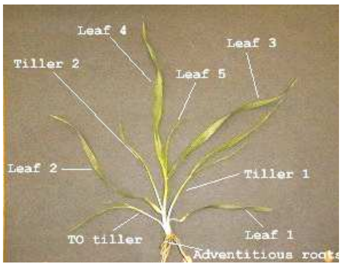
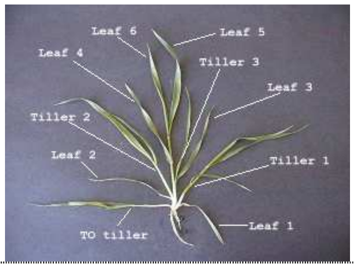
4. Booting	49. 	49. (Aug 5, 51-100 cm) 
6. Flowering	60.  	60. (Aug 8, > 1 m) 
8. maturity	89. 	89. (Aug 29, > 1 m) 
9. Senescence	99. 	99. (Sept 9, 16-30 cm) 

1.3. Wheat

1.3.1. General

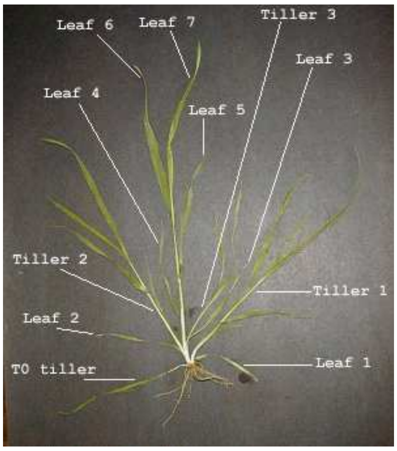
In Manitoba wheat is planted between May 1st and May 31st and is harvested between August and October. Plant density is typically 23-28 plants/ft^2 (MAFRI, 2011). In 2009 and 2010 wheat covered the second largest seeded area of all crops at 1, 228 and 4, 000 thousand hectares. Canola covered the largest area at 1, 295 and 2, 828 thousand hectares (STATCAN, 2011).

1.3.2. Example Growth Timeline (UIE, 2012)

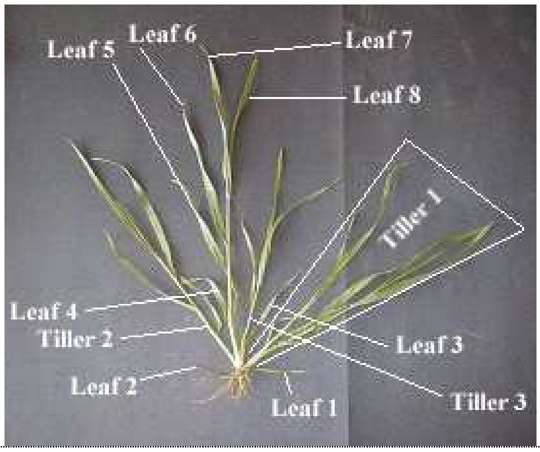
Growth Stage	Photos of Single Plants	Photos of Fields
1. Leaf Development	11. 	11. 
	12. 	12. 
2. Tillering	21. 	21. 
	23. 	23. 

<table>
<tr>
<td>3. Stem Elongation</td>
<td>

31.



39.



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31.

39.


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<tr>
<td>4. Booting</td>
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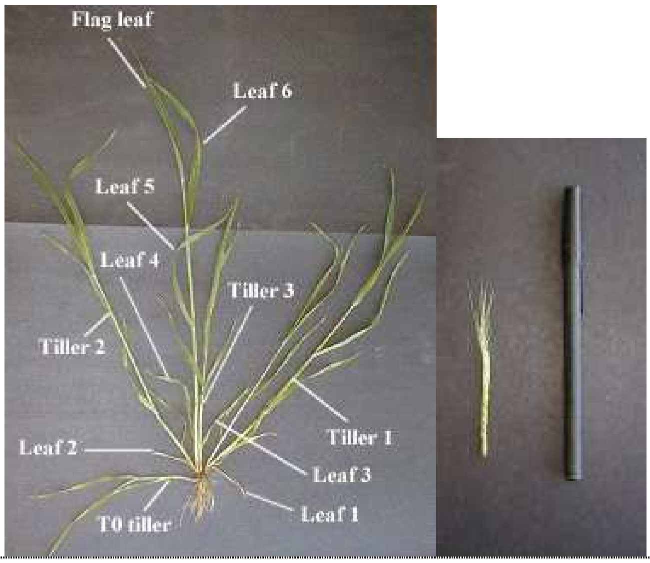
45.



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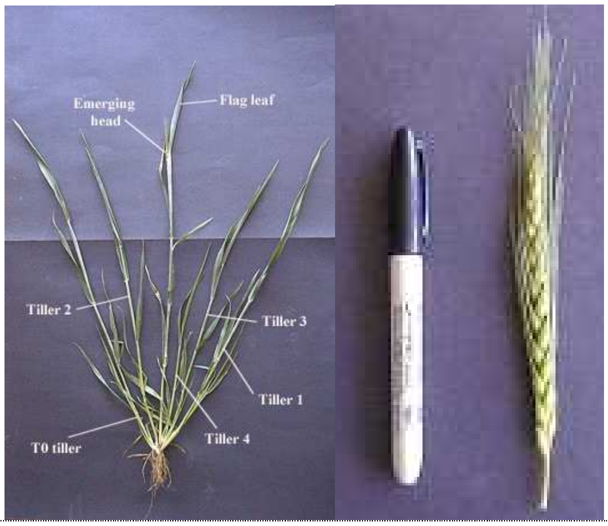
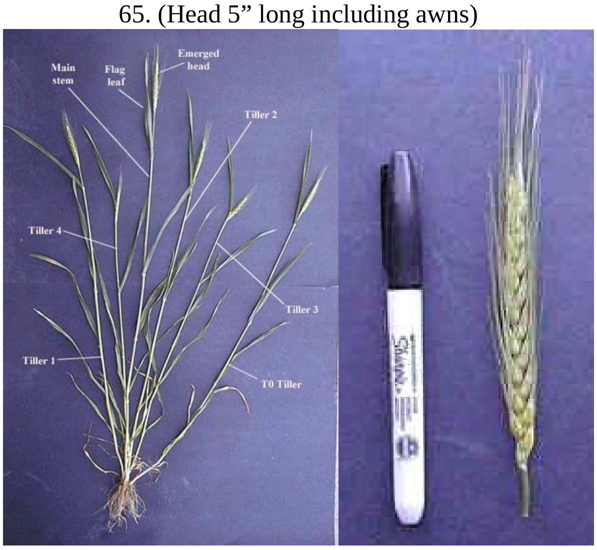
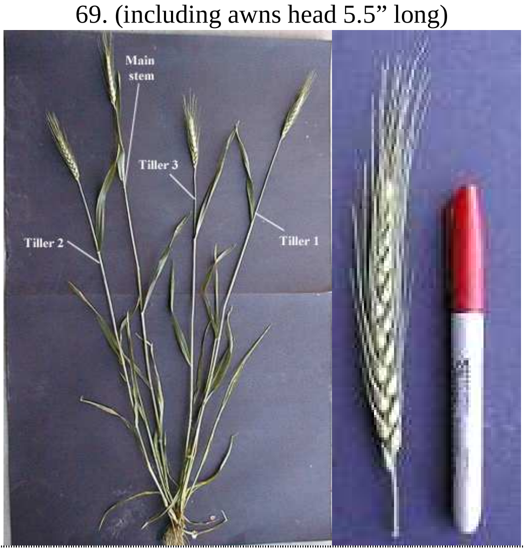
5. Inflorescence Emergence, Heading	53.  	53. 
6. Flowering/Anthesis	65. (Head 5" long including awns)  69. (including awns head 5.5" long)  	65.  69. 

<table>
<tr>
<td rowspan="2">7. Development of Fruit</td>
<td>73.

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<td>73.
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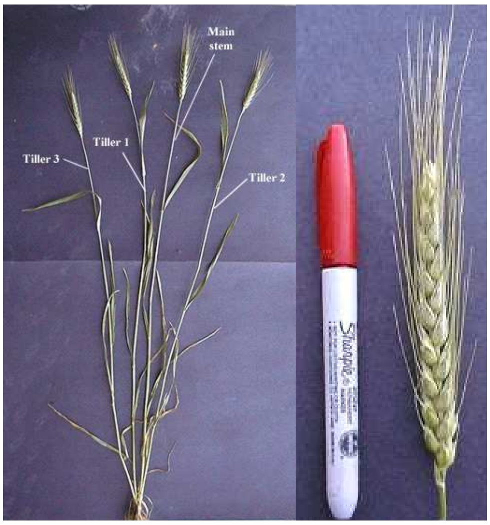
<tr>
<td rowspan="2">8. Ripening</td>
<td>85.

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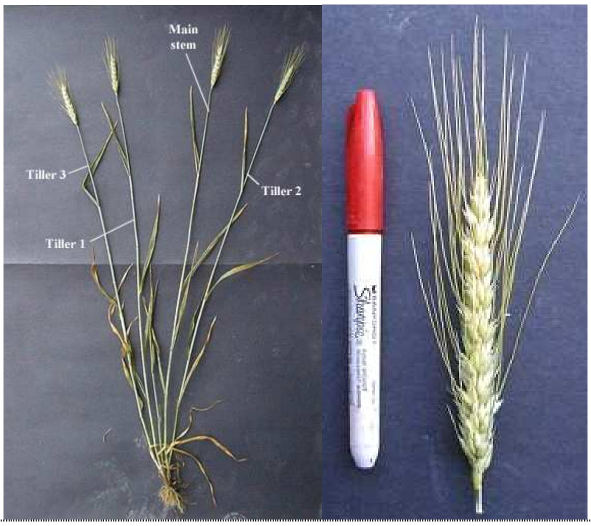
<td>87.

</td>
<td>87.
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</table>

9. Senescence

91.

91.

92.

92.

2.0. Corn

2.1. General

In Manitoba corn is planted between May 1st and May 15th. Row spacing is typically 30-36", though 20" rows may also be encountered. In some cases corn will be planted in a no-till method. This means that you may notice "stubble" in the field, including soybean stubble (Figure 23).

Figure 23: Corn plant emerging through soybean stubble. Photo shows plants at BBCH: 10 (Nielsen, 2003).

2.2. Identifying Growth Stages: BBCH Scale

The following provides a description of the main developmental stages for corn based on the BBCH scale (Table 2). When staging corn remember to consider the plant(s) that is most representative of average field conditions (Ritchie et al. 1993).

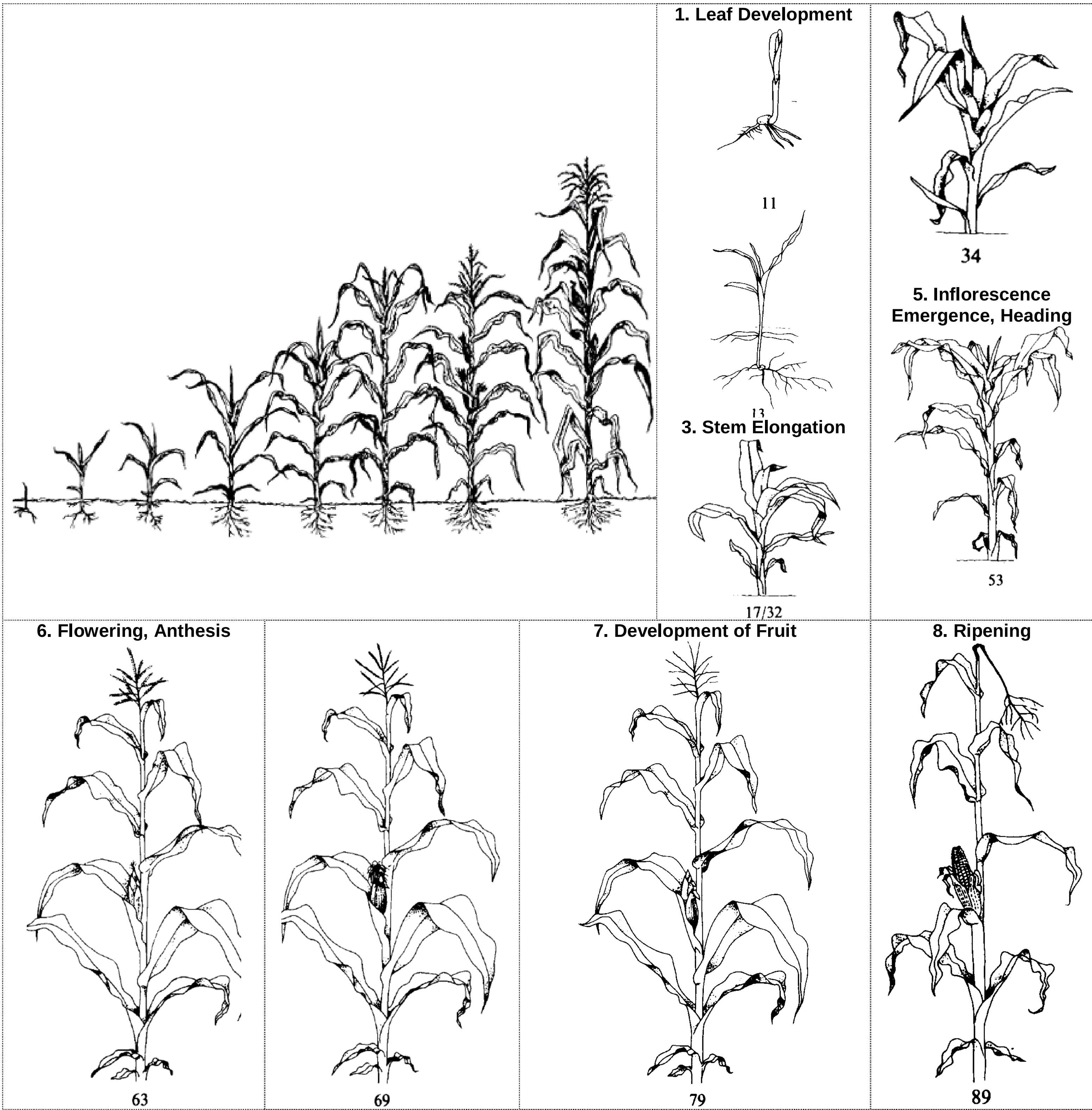
Table 3: BBCH growth stages for corn.

	0. Germination
00	Dry seed (caryopsis)
01	Beginning of seed imbibition
03	Seed imbibition complete
05	Radicle emerged from caryopsis
06	Radicle elongated, root hairs/side roots visible
07	Coleoptile emerged from caryopsis
09	Coleoptile penetrates soil
	1. Leaf Development[1]
10	First leaf through coleoptile
11	First leaf unfolded
12	2 leaves unfolded
13	3 leaves unfolded
1…	Stages continuous till …
19	9 or more leaves unfolded
	3. Stem Elongation[2]
30	Beginning of stem elongation
31	First node detectable
32	2 nodes detectable
33	3 nodes detectable
3…	Stages continuous till…
39	9 or more nodes detectable[1]
	5. Inflorescence Emergence, Heading
51	Beginning of tassel emergence, tassel detectable at top of stem
53	Tip of tassel visible
55	Middle of tassel emergence: middle of tassel begins to separate
59	End of tassel emergence: tassel fully emerged & separated
	6. Flowering, Anthesis
61	Male: stamens in middle of tassel visible Female: tip of ear emerging from leaf sheath
63	Male: beginning of pollen shedding Female: tips of stigmata visible
65	Male: upper & lower parts of tassel in flower Female: stigmata fully emerged
67	Male: flowering completed Female: stigmata drying
69	End of flowering: stigmata completely dry
	7. Development of Fruit
71	Beginning of grain development: kernels at blister stage, about 16% dry matter
73	Early Milk
75	Kernels in middle of cob yellowish-white (variety-dependent), content milky, about 40% dry matter
79	Nearly all kernels have reached final size
	8. Ripening
83	Early dough: kernel content soft, 45% dry matter.
85	Dough stage: kernels yellowish to yellow 55% dry matter
87	Physiological maturity: black dot/layer visible at base of kernels, 60% dry matter
89	Fully ripe: kernels hard & shiny, 65% dry matter
	9. Senescence
97	Plant dead & collapsing
99	Harvested product

[1] Tillering or stem elongation may occur earlier than stage 19; in this case continue with principal growth stage 3

[2] In maize, tassel emergence may occur earlier, in this case continue with principal growth stage 5.

From Sprouting to Ripening



0. Sprouting/Germination

It will not be essential to identify stages 00 to 08, as these occur below the soil surface. At stage 09 the coleoptile penetrates the soil. It is a rigid feature of the plant that contains the tissue of first leaves.

1. Leaf Development

Following penetration of the surface by the coleoptile, the first leaf of the plant emerges (Figure 3). The plant is identified as BBCH: 10, since the leaf has not completely unfolded. Note that in comparison to cereals the leaf is thicker and larger.

Figure 24: Corn plant emerging through soil surface with first leaf just through the coleoptile. Photos show plants at BBCH: 10 (Nielsen, 2010).

The first true leaf of a corn plant is known as the “thumb” or flag, because of its round shape. If this leaf is full developed (described subsequently) it should be counted. It is the only rounded leaf on the plant and into later developmental stages may be missing due to damage or because it has dried out (Hager et al., 2006).

Figure 25: Corn plant well past emergence to show first “thumb” leaf (Nielsen, 2010).

In the BBCH scale leaves are counted only when they have completely unfolded. This may otherwise be known as the “droopy” leaf method. Though it is best to stick with this method for staging plants, there is another widely used method that should be considered in the field. This is the “collar counting” method (Nielsen, 2010). **Note: In some case you may want to dissect the plant down the stem to get a better look at the number of leaves.*

1.1. Collar Method for Determining Leaf Development Stage

For this method stem collars (base of leaves where blades attach to stems) are counted to stage plants (Figure 26). Collars are usually a lighter colour than the rest of the plant, and are well developed when the leaf is hanging mostly outside the whorl (Hager et al. 2006). The collar method may be easier to use if the plant has been damaged (e.g. due to hail), as this may result in missing leaves. By comparison the “droopy leaf” method usually places plants one to two steps ahead in the BBCH scale. Note, the collar of the “thumb leaf” is the first collar of the plant (Ritchie et al. 1993; Hager et al., 2006).

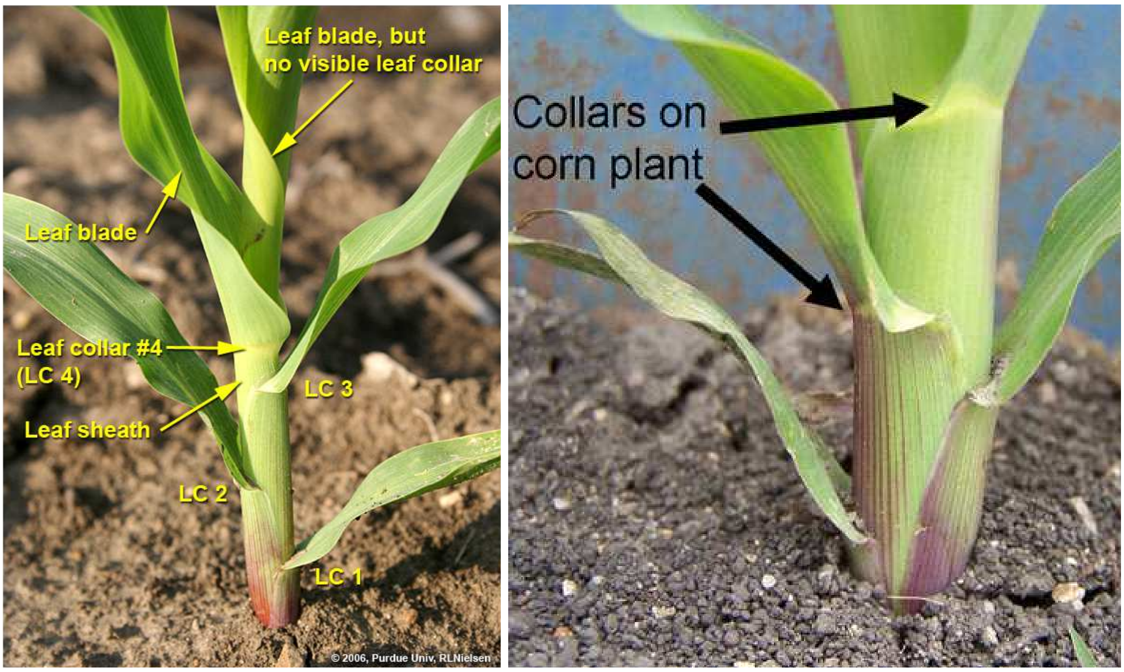


Figure 26: Photo of a corn plant with four visible collars, corresponding to BBCH: 14 (left → Nielsen, 2010 and right → Ritchie, 1993).

The following provides additional photos of plants at various leaf stages, as counted by the number of collars.

One Collar

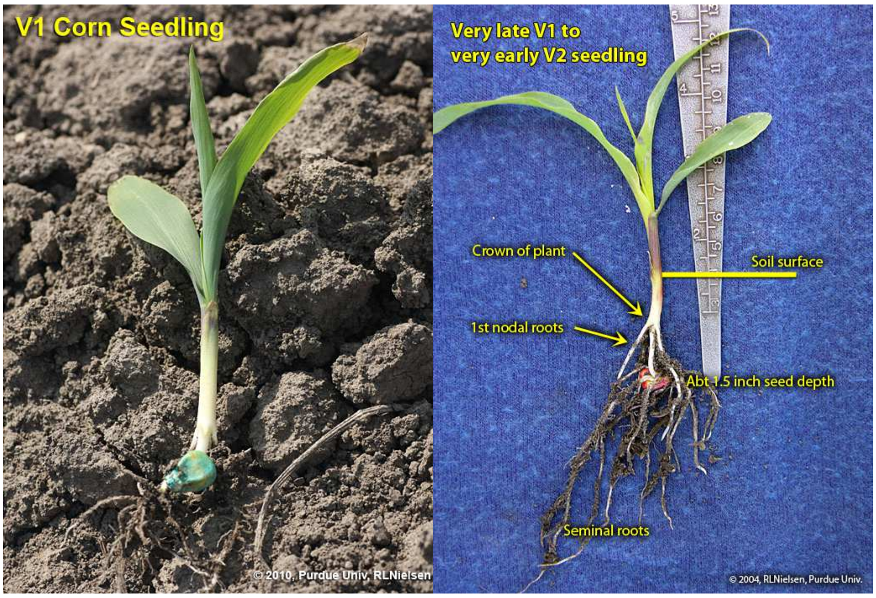


Figure 27: Photo of a corn plant with one visible collar at early (left) and late (right) stage. Photo shows plant at BBCH: 11 (left) and BBCH: 12 (right) (Nielsen, 2004).

Two Collars

Figure 28: Photos of a corn plant with two visible collars. Photos show plant at BBCH: 13 (Ritchie, 1993).

Three Collars

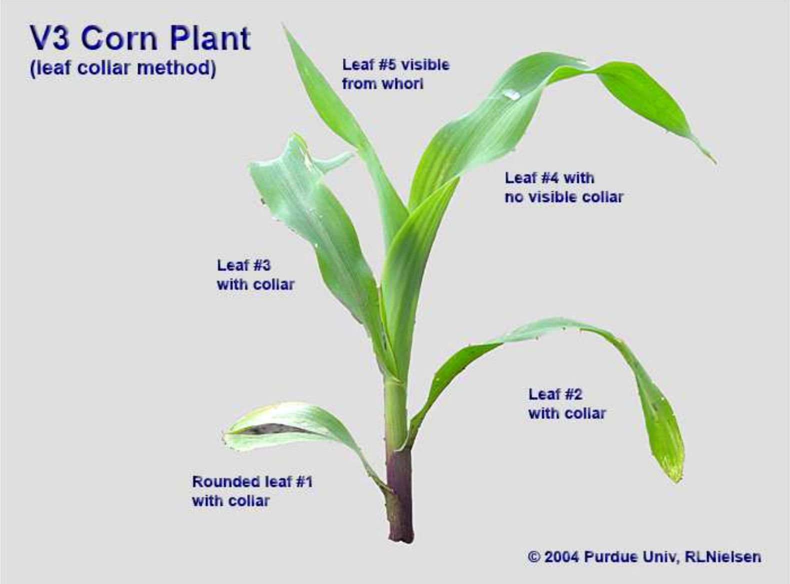


Figure 29: Photo of a corn plant with three visible collars. Photo shows plant at BBCH: 14 (Nielsen, 2010).

Four Collars

Figure 30: Photo of a corn plant with four visible collars. Red arrows are used to indicate the counted collars. Photo also shows plant at about BBCH: 14 (Hager et al., 2006).

1.2. Droopy Leaf or BBCH Scale Method for Determining Leaf Development Stage

To count the number of leaves of the plant, first begin with the “thumb” leaf at the base. All subsequent leaves that are at least 50% outside the whorl and or have tips hanging below the horizontal (Figure 31) are counted (Hager et al., 2006). At this point it should be fully unrolled. This should be the preferred method for staging plants, though as mentioned previously it may be helpful to count the number of collars (Nielsen, 2010).

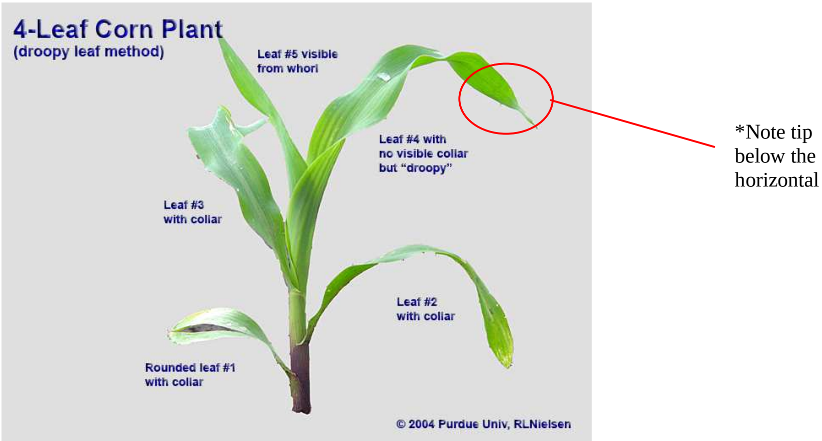


Figure 31: Corn plant with four leaves outside the whorl, representing BBCH: 14 (Nielsen, 2010).

3. Stem Elongation

If the plant is in this stage of development, you will be able to detect nodes along the stem. In the early stages of development it is necessary to dissect the plant along the stem in most cases, as many of the nodes will be close to the soil surface (Figure 32). Nodes appear as dense masses of plant material above the pith. It should be noted that the fifth leaf is usually attached to the first node (Nielsen, 2010). In later stages nodes should also become more visible, as round bulges along the outside of the stem.

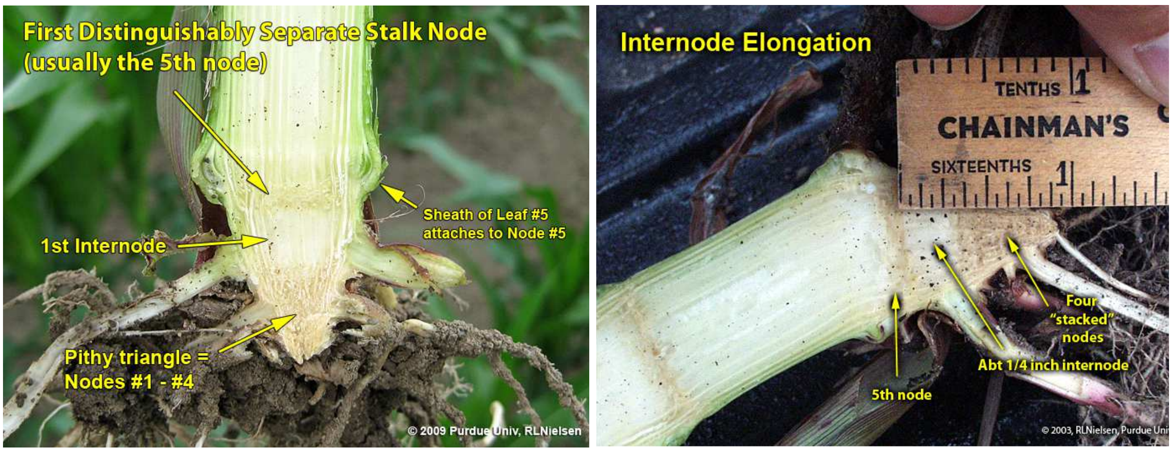


Figure 32: Left shows dissected plant to expose the first node, representing BBCH: 31 (Nielsen, 2010), and right shows a dissected corn plant with five nodes, representing BBCH: 35 (Nielsen, 2004)

5. Inflorescence Emergence, Heading

Nodes are counted until the tassel becomes visible at the top of the stem, representing BBCH: 51 (Figure 33). At this stage the tassel may be wrapped in a leaf inside the whorl, making it difficult to see. Note that in most cases the plant will begin tasseling at BBCH: 15 or when five or more leaves have formed (Nielsen, 2004). To stage the plant you may have to un-wrap this leaf and or dissect the stem.

Figure 33: Photo of corn plant at the beginning of tasseling, representing BBCH: 51(Ritchie, 1993).

Figure 34 (left) shows a plant with nine leaves (BBCH: 19), which when dissected shows about 8 nodes and an already well developed tassel emerging at the top of the stem (BBCH: 55). As you can see in the photo, dissecting the stalk can help you see how much of the tassel has emerged from the whorl.

Figure 34: Photo of dissected corn plant to expose the nodes, representing BBCH: 55 (Nielsen, 2000).

When the tassel is fully emerged (BBCH: 59) the field may look similar to Figure 35. Full tassel emergence usually occurs 50 days after the plant has germinated (Kling et al., 1997). At this point the tassel should be fully separated from the whorl and other leaves. Tassels are also composed of several branches (Figure 35).

Figure 35: Left side shows photo of corn field tasseling, representing BBCH: 59 (Nielsen, 2004), and right side shows an illustration of one corn tassel with its multiple branches (Kling et al., 1997).

6. Flowering, Anthesis

BBCH: 61

The flowering/anthesis stage (BBCH: 61) begins when you can see anthers on the middle branch of the tassel, which is where they first develop. These are the male stamens of the plant (Figure 36). These stamens include anthers and their filaments that attach them to the floret (Figure 36). Anthesis is the process by which pollen from anthers is released (Kling et al., 1997).

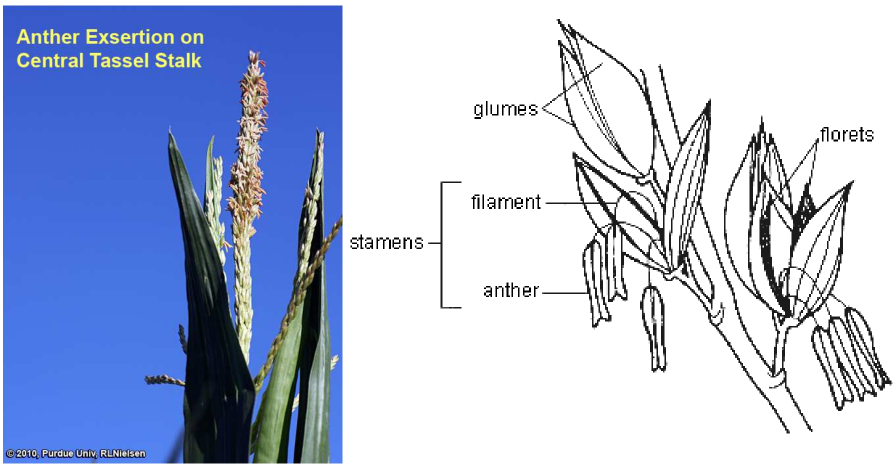


Figure 36: Left is a corn plant at the start of flowering, anthesis stage, representing BBCH: 61 (Nielsen, 2004), and right shows an illustration of filaments and anthers of the florets.

Also at BBCH: 61 you will start to see the corn ear emerging from the leaf sheath.

Figure 37: Corn ear at early stages of emergence from leaf sheath (Nielsen, 2004).

BBCH: 63

At BBCH: 63, pollen shed begins for corn plants (Figure 38). This may occur sporadically within a field and take up to two weeks for the entire field to finish pollination. When the plant is pollinating you will see open pores on anthers (Nielsen, 2004).

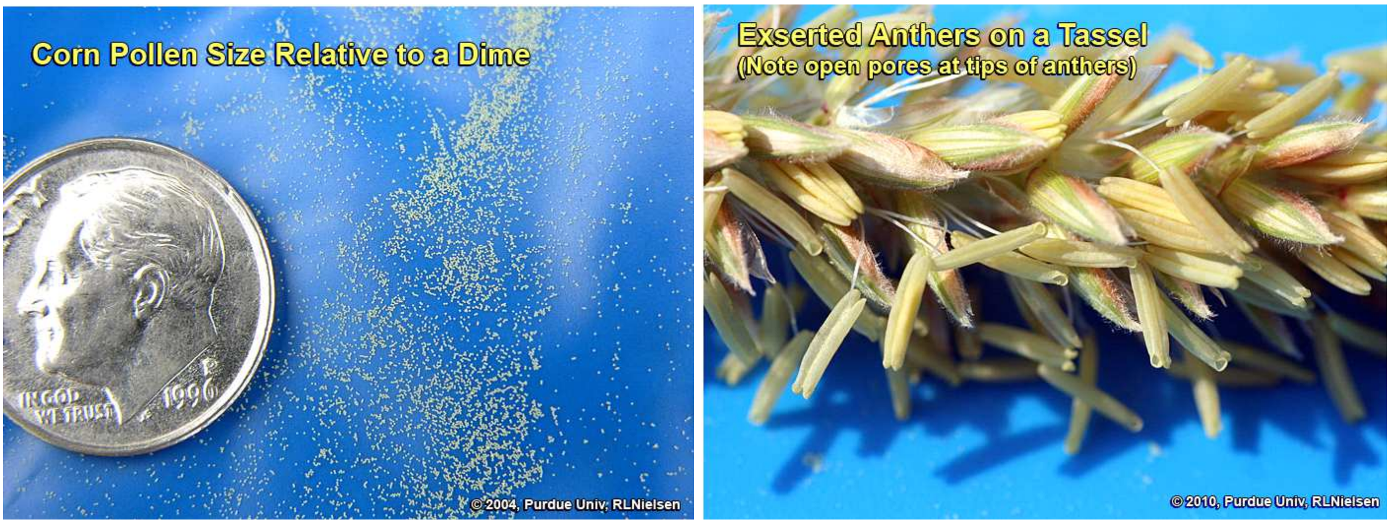


Figure 38: Left is a photo of corn pollen and right is a photo of anthers with open pores, representing BBCH: 63 (Nielsen, 2004)

At this point you should also start to see silks emerging from the corn husks. This is the female stigmata, that catches falling pollen for pollination of kernels inside the husk. For this reason there is one silk per kernel (Nielsen, 2004). To stage plants you may need to un-wrap the husk to determine how much of the silk has emerged. At the time silks start to emerge the corn ear should look like it does in Figure 39.

Figure 39: Left shows outside appearance of corn ear at time of BBCH: 63, where silks are beginning to emerge from the husk, and right shows cob inside husk at this time (Nielsen, 2010).

BBCH: 65

At this stage of development the upper and eventually the lower (as they are the last to develop) branches of the tassel should contain anthers, shedding pollen. Corn silks have completely emerged from the husk. Silk length and colour may vary by plant, varieties and fields, but remember that silks should not be too dry or dark in colour at the time of early emergence (Figure 40).

Figure 40: Appearance of ear of corn at early silk emergence, representing BBCH: 65 (Nielsen, 2010).

BBCH: 67 & 69

At this stage corn silks are turning a darker colour, and are beginning to dry out. At this time there may be missing anthers due to them drying out and falling off.

Figure 41: Appearance of ear of corn at the time of silk dry down, representing BBCH: 67 (Nielsen, 2010).

7. Development of Fruit

Stages 7 (Development of Fruit) and 8 (Ripening) are less important to identify as much of the plant development occurs only in the cob. Note that the cob will increase in size as the kernels fill with milk(Figure 42).

Figure 42: Appearance of ear of corn at the time of milk and dough stage, representing BBCH: 75 and BBCH: 85 (Nielsen, 2001).

9. Senescence

Senescent corn is yellow to white in colour and typically contains fewer leaves, and in some cases no tillers. Plants may also be shorter than previously. Corn is not usually harvest ready until October to November in Manitoba and so plants at this stage will not likely be encountered.

Figure 43: Appearance corn in the field at the time of senescence, representing BBCH: 99, as well as an ear of corn at the same time (NCB, 2010).

2.3. Example Growth Timeline

The following photos, timeline, and height measurements provides an example of growth over time in a typical corn field (Figure 44).

Figure 44: Photos, timeline and height measurements for a typical corn field (AAFC, 2012).

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