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Chapter

26

Seed Germination

Seed germination represents the means for survival and spread of many plants (McDonough 1977). Germination consists of three overlapping processes: (1) absorption of water, mainly by imbibition, causing swelling of the seed; (2) concurrent enzymatic activity and increased respiration and assimilation rates; and (3) cell enlargement and divisions resulting in emergence of root and plumule (Evanari 1957; Schopmeyer 1974b).

Germination is most commonly expressed as germination capacity, which is the percentage of seed that germinates during a period of time that ends when essentially all germinable seed have germinated. Germination energy is sometimes used in the literature. Germination energy is the percentage of seed that germinates during a specific time interval that is determined by the peak of germination. Germination capacity and germination energy will generally vary considerably within a seed lot (table 1).

Table 1—Mean germination energy and mean germination capacity of 18 grass, 27 forb, and 28 shrub species following specified number of days. Germinated in the dark at 34 to 38 °F (1.1 to 3.3 °C).

Species	Germinative energy[a] Percent	Days	Germinative capacity[b] Percent	Days	Number of accessions[c]
Grasses					
Bluegrass, Kentucky	27	70	30	365	6
Brome, mountain	54	38	77	120	7
Brome, meadow, ‘Regar’	90	28	92	42	6
Brome, smooth southern	67	21	80	49	12
Fescue, hard sheep	58	30	82	60	12
Foxtail, meadow	75	30	80	75	8
Orchardgrass	70	28	91	45	7
Orchardgrass, ‘Paiute’	30	56	72	112	16
Rye, mountain	45	30	49	60	5
Squirreltail, bottlebrush	75	28	95	49	8
Wheatgrass, bluebunch	85	21	93	45	8
Wheatgrass, standard crested	78	30	88	80	8
Wheatgrass, fairway crested ‘Ephraim’	90	28	92	42	30
Wheatgrass, intermediate	70	28	93	50	24
Wheatgrass, pubescent ‘Luna’	70	28	93	50	10
Wheatgrass, tall	75	30	90	120	10
Wildrye, Great Basin ‘Magnar’	53	50	75	250	18
Wildrye, Russian	70	28	91	49	12
Forbs					
Alfalfa ‘Ladak’	85	14	92(3)[d]	28	30
Alfalfa ‘Nomad’	56	14	94(3)[d]	45	16
Aster, Pacific	34	120	59	180	8
Aster, Engelmann	80	150	83	180	4
Aster, blueleaf	26	90	48	180	4
Balsamroot, arrowleaf	26	98	40	175	12
Balsamroot, cutleaf	17	98	35	180	10
Burnet, small	80	21	91	35	16
Clover, strawberry	56	60	91	365	4
Cowparsnip	30	150	64	365	6
Crownvetch	35	45	55(20)[d]	180	12
Flax, Lewis ‘Appar’	70	45	80	75	22
Geranium, Richardson	16	180	22	365	4
Goldeneye, showy	20	150	27	365	7
Helianthella, oneflower	50	90	90	180	10
Lomatium, narrowleaf	49	130	72	365	8
Lupine, mountain	63	36	77	98	16
Lupine, silky	73	56	95	98	10
Milkvetch, cicer	20	75	32(65)[d]	150	18
Penstemon, low	21	150	42	365	4
Penstemon, Palmer ‘Cedar’	62	49	86	63	10
Sainfoin	80	21	91	35	10
Salsify, vegetable oyster	48	35	63	130	8
Sweetanise	34	180	60	365	8
Sweetvetch, Utah (shelled)	40	50	63	200	20
Sweetvetch, Utah (unshelled)	28	50	34	210	10
Sweetclover, yellow	75	14	90	42	22
Shrubs					
Apache plume	23	60	63	180	8
Bitterbrush, antelope	72	42	90	56	40
Bitterbrush, desert	58	28	86	70	12
Ceanothus, Martin[e]	33	120	38	240	8
Chokecherry, black	32	150	72	365	8

(con.)

Table 1 (Con.)

Species	Germinative energy[a] Percent	Days	Germinative capacity[b] Percent	Days	Number of accessions[c]
Shrubs					
Cliffrose	70	70	84	91	18
Currant, golden	37	90	70	365	7
Ephedra, green	74	56	91	70	18
Ephedra, Nevada	80	21	93	35	12
Greasewood, black[e]	30	45	46	180	4
Hopsage, spiny	60	40	82	120	18
Kochia, forage 'Immigrant'	60	35	87	49	30
Mountain mahogany, curlleaf	53	105	68	365	16
Mountain mahogany, true	64	63	83	112	20
Peachbrush, desert	57	45	75	180	8
Rabbitbrush, mountain low	63	180	73	365	6
Rabbitbrush, mountain rubber	55	49	72	63	8
Rabbitbrush, whitestem rubber	60	42	70	56	22
Sagebrush, basin big	60	63	61	70	36
Sagebrush, black	59	42	75	91	14
Sagebrush, fringed	15	74	36	365	4
Sagebrush, mountain big	45	48	82	104	32
Sagebrush, Wyoming big	38	48	76	104	12
Saltbush, fourwing[e]	26	42	39	63	60
Saltbush, Gardner[e]	16	90	24	180	8
Serviceberry, Saskatoon	63	330	80	365	12
Serviceberry, Utah	77	104	94	210	10
Winterfat	55	14	84	28	24

[a]Percentage of seed that germinate during a specific time interval that is determined by the peak of germination.
[b]Percentage of seed that germinate during a period of time ending when essentially all germatable seed have germinated.
[c]Number of accessions used in determining results. Two 100 seed samples per accession were evaluated.
[d]Percent hard seed in parenthesis.
[e]Fifty percent fill, all other species 95 to 100 percent fill.

A mature, viable nondormant seed (fig. 1) will germinate (fig. 2) if placed under favorable conditions of moisture, temperature, gas exchange, and light (for some species). There is an interdependence between these factors as well as between age of seed and storage conditions. The conditions that allow germination to occur and the time required for germination can vary dramatically between seed lots of a species (Meyer and Monsen 1990; Meyer and Pendleton 1990; Meyer and others 1987, 1989; Stevens and Jorgensen 1994; Young and others 1984d).

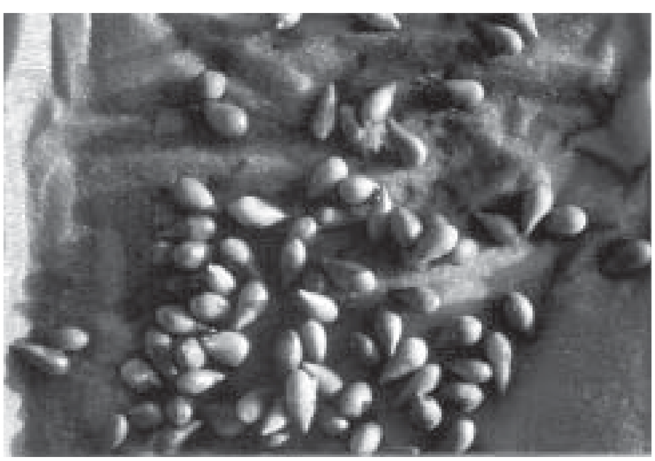


Figure 1—Mature, viable antelope bitterbrush seed.

Figure 2—Germinating antelope bitterbrush seed.

Moisture

The cells of the germinating seed cannot carry on the vital process of germination without sufficient water. The rate of water absorption is largely dependent upon the degree of seedcoat permeability and availability of water. Seedcoat permeability and rate of water uptake can be increased in some species by mechanical, chemical, or hot water treatments (see chapter 24). Seeds of some species will absorb the amount of water required for germination in a short period; others take a much longer period. Rubber rabbitbrush will absorb the amount of water required for germination in about 36 hours, whereas seed of blue elderberry requires a much longer period: 180 days or more.

Too much water can be harmful to some seeds. Most can be soaked in water for 3 to 5 days without decreasing germination, but care should be taken if seed is soaked for longer periods.

Temperature

Seeds of many species can germinate over a wide range of temperatures. Others germinate only within narrow temperature ranges (Schopmeyer 1974b). Seed of several plant species have the capacity to germinate at temperatures close to 32 °F (0 °C). Right after snow melt, soil temperatures are generally low and soil water levels are high. Under these conditions, those seeds that germinate at low temperatures have a good chance for survival, with adequate moisture being available for continued growth.

Knowing the temperature or combination of temperatures at which a species will exhibit maximum germination can help in determining the most ideal time to sow the seed. Optimum germination temperatures have been determined for a number of shrubs (Allen and others 1986a,c, 1987; Dettori and others 1984; Evans and Young 1977a; Springfield 1972a; Young and others 1981a; Young and Evans 1981b), cool season grasses (Allen and others 1986b; Young and Evans 1978a, 1981a, 1982, 1984; Young and others 1981a), and forbs (Allen and Davis 1986; Allen and others 1986b; Young and Evans 1979).

Extreme high temperature, such as in a fire can increase germination and emergence of species like buckbrush, smooth sumac, and lodgepole pine. Rupture of the seedcoat structure and heat inactivation of inhibitors are possible explanations for the effect fire has on seed germination (McDonough 1977).

Gas Exchange

Most seeds will not germinate when the soil is too wet, when seeds are planted too deep, or when conditions limit the supply of oxygen. Oxygen has to be present for germination to take place. A low rate of oxygen uptake permits only the earliest stages of germination to occur. If a continual source of oxygen is not available, germination will stop and the seed will die. Oxygen is also essential for normal seedling development. Oxygen requirements can affect seeding time, seeding depth, and selection of areas to seed. The rate of oxygen absorption during seed germination and seedling development is highly variable among species (Schopmeyer 1974b).

Light

Under natural conditions, some seeds become buried and germinate without light. However, light is essential for seed germination of many species. Depth of seeding should be controlled as well as possible when sowing seeds of species having a light requirement (Schopmeyer 1974b). Indian ricegrass, western wheatgrass, and Great Basin wildrye are a few species that germinate best in the dark (seed covered). Mountain brome, slender wheatgrass, blue grama, big sagebrush, and forage kochia are species that require light to germinate.

Afterripening

Another factor encountered in the germination process is afterripening or a continuation of the maturing process after harvest. There are a number of grasses, forbs, and shrubs that exhibit afterripening (Stevens and Jorgensen 1994) (table 2; also see chapter 24). Seed that has been collected before fully ripening, or seed freshly harvested can, initially, exhibit low germination that will increase after a period of air-dry storage. This process hardens the embryo, and in some instances helps increase the ability of the seed to absorb the water needed for the germination process. Whether or not afterripening occurs depends upon a number of factors, including site differences, degree of seed maturity at harvest, conditions of storage, and ecotypic differences within species (McDonough 1977).

Dormancy

Viable and uninjured seeds of most shrub species will not germinate without seed dormancy being broken or overcome. The degree of seed dormancy varies between species (fig. 3; table 2; also see chapter 24). For example, forage kochia and winterfat only require afterripening, whereas, wildrose and blue elderberry require 1 or 2 years or cold moist stratification to break dormancy. Most grasses exhibit little dormancy. An exception is Indian ricegrass (Young and Evans 1984), which exhibits a profoundly dormant embryo. Seed of most forb species, with the exception of the legumes, posses a moderate level of dormancy. Many

Table 2—Mean percent germination of seed from 39 plant species after 2 to 25 years of storage in an open warehouse (Stevens and Jorgensen 1994).

Species	Source	Years of storage								
		2	**3**	**4**	**5**	**7**	**10**	**15**	**20**	**25**
		Percent germination[a,b,c,d]								
Grasses										
Intermediate wheatgrass	Washington	95	96	93	94	80	78–	63	13	1
Smooth brome	Colorado	70	71–	52	39–	15	11	3	1	0
Winter rye	Idaho	89	88	82	75–	56	48	32–	2	0
Forbs										
Alfalfa	Canada	69	76	75	75	70	77	66	73	67
	same + hard seed	92	95	94	92	79	86–	71	78	71
Balsamroot, arrowleaf	Paradise Valley, NV	40	42		37–	20	1	0	0	0
Balsamroot, cutleaf	Bountiful, UT	35	28–	17	20–	4	0	0	0	0
Burnet, small	Ephraim, UT	88*+	93	91	96–	82	87	88–	69+	83
Cowparsnip	Pleasant Cr. Canyon, UT	7	8–	2	1	0	0	0	0	0
Eriogonum, Wyeth	Brigham City, UT	51*+	87		90–	64–	16–	5	–	0
Flax, Lewis	Ephraim, UT	66*	72*+	85	93	83	70–	25	8	0
Globemallow, gooseberry	Benmore, UT	7	7	6	9	6	7	6	–	2
Goldeneye, showy	Ephraim Canyon, UT	18	17	11	13	13–	1	0	0	0
Ligusticum, Porter	Ephraim Canyon, UT	41	28	24	36–	13	0	0	0	0
Lomatium, Nuttall	Ephraim Canyon, UT	69	73		73–	37–	8	2	0	0
Lupine, mountain	Ephraim Canyon, UT	58	77	69	60–	26	28	13	6	1
Lupine, silky	Ephraim Canyon, UT	97	99	100	99–	86	85	92–	75	76
Penstemon, Palmer	Ephraim Canyon, UT	83	81		79–	65	50		–	0
Salsify, vegetable-oyster	Mt. Pleasant, UT	65	65	66	66–	46	31–	13	0	0
Sweetvetch, Utah	Orem, UT	59	67	58	55–	25	40	16	11	21
Shrubs										
Bitterbrush, antelope	Mt. Dell, UT	79*+	86	87	94	88	88	85	84–	74
Bitterbrush, desert	Bishop, CA	78	86	80	80	69	73	65	61	60
Ceanothus, Martin	Manti Canyon, UT	3	5	5	12	10+	40	36–	5	6
Cliffrose	American Fork, UT	80*+	89		89	84	89	91–	66	63
Currant, golden	Manti, UT	48		–	28		27–	6	2	0
Ephedra, green	Manti, UT	88	92	92	84	80	82	88–	24	2
Ephedra, Nevada	Wah-Wah Valley, UT	90	93	91	85	89	91	85–	79	77
Hopsage, spineless	Escalante, UT	87	92	86–	57–	13	6	0	0	0
Indian apple	Ephraim Canyon, UT	42	42	42	37	39–	21	10–	–	0
Mountain mahogany, curlleaf	Mayfield, UT	67	63		80	76	69	64–	44	28
Mountain mahogany, true	Ephraim Canyon, UT	63	65	61	68–	46–	25–	3	0	0
Rabbitbrush, whitestem rubber	Richfield, UT	80–	65–	34–	14	11–	7	0	0	0
Sagebrush, basin big	Ephraim, UT	73	82	67	70–	24–	1	0	0	0
Sagebrush, black	Manti, UT	81–	66	55–	34–	5	1	0	0	0
Saltbush, fourwing	Panaca, NV	32	47	40	40	50	43	37–	18	11
Serviceberry, Saskatoon	Spring City Canyon, UT	91	80		91	85–	72	76–	1	0.3
Serviceberry, Utah	Henrieville, UT	97	99		99	96	90–	67–	5	0
Snowberry, mountain	Spanish Fork Canyon, UT	80	64		92	80–	44–	8	10	8
Winterfat	Corona, NM	90	83	74–	18	7	0	0	0	0

[a]Results based on four samples of 100 seeds each at 98 percent or better fill and 100 percent purity, except fill for fourwing saltbush (52 percent fill) and Martin ceanothus (59 percent fill).
[b]Asterisk (*) indicates significant afterripening.
[c]Plus sign (+) indicates significant increase in germination between adjoining years at the 0.5 level.
[d]Minus sign (–) indicates significant decrease in germination between adjoining years at the 0.5 level.

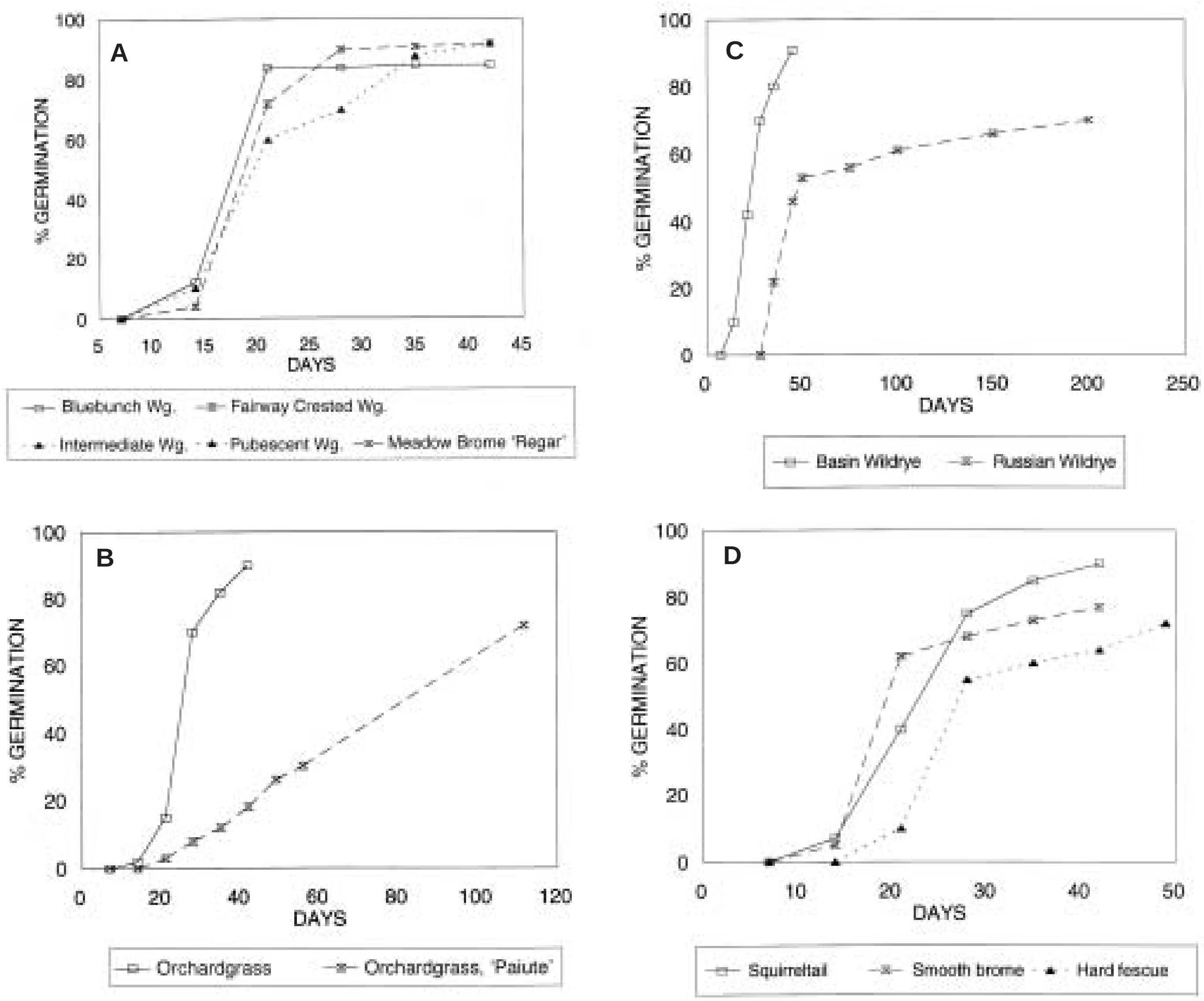
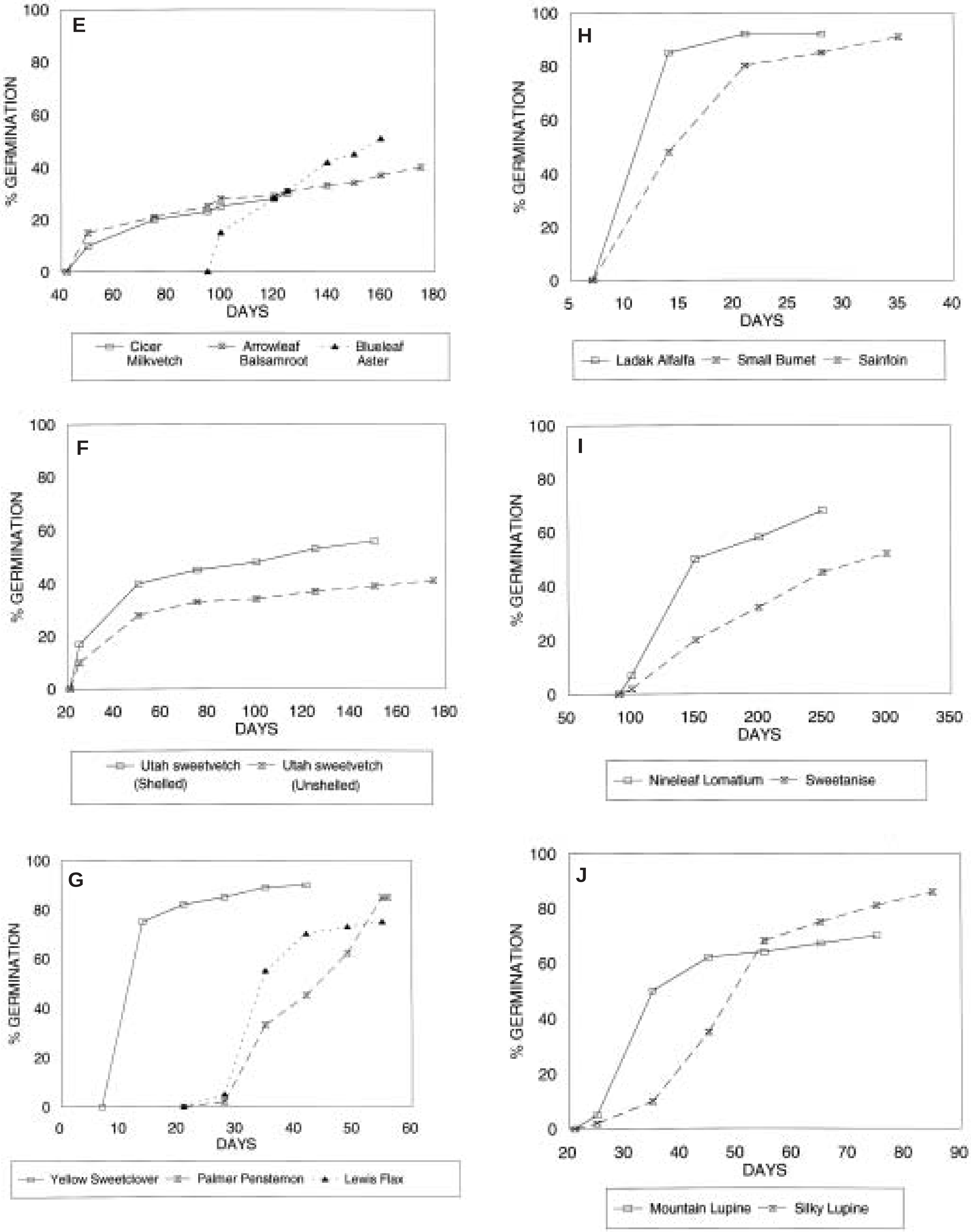


Figure 3—Mean germination over time of multiple accessions (number of accessions listed in parenthesis following common name) of selected grasses, forbs, and shrubs in the dark at 34 to 38 °F (1.0 to 3.3 °C). Two samples of 100 seeds each examined for each accession.

A. Bluebunch wheatgrass (8), fairway crested wheatgrass (8), meadow brome, 'Regar' (6), intermediate wheatgrass (24), and pubescent wheatgrass (10).
B. Orchardgrass (7), and orchardgrass, 'Paiute' (16).
C. Great Basin wildrye (18) and Russian wildrye (12).
D. Bottlebrush squirreltail (8), smooth brome (6), and hard sheep fescue (12).
E. Cicer milkvetch (18), arrowleaf balsamroot (8), and blueleaf aster (8).
F. Utah sweetvetch with seed out of loment (10), and Utah sweetvetch with seed in loment (20).
G. Yellow sweetclover (22), Palmer penstemon (10), and Lewis flax (32).
H. 'Ladak' alfalfa (30) and small burnet (10).
I. Nineleaf lomatium (8) and sweetanise (8).
J. Mountain lupine (16) and silky lupine (10).
K. Wyoming big sagebrush (12), basin big sagebrush (36), mountain big sagebrush (32), and black sagebrush (14).
L. Antelope bitterbrush (40) and cliffrose (18).
M. Winterfat (24), forage kochia (30), and fourwing saltbush (61).
N. Whitestem rubber rabbitbrush (22), green ephedra (18), and true mountain mahogany (20).
O. Curlleaf mountain mahogany (16) and black chokecherry (8).

Figure 3 (Con.)


E
% GERMINATION
DAYS
Cicer Milkvetch
Arrowleaf Balsamroot
Blueleaf Aster
H
% GERMINATION
DAYS
Ladak Alfalfa
Small Burnet
Sainfoin
F
% GERMINATION
DAYS
Utah sweetvetch (Shelled)
Utah sweetvetch (Unshelled)
I
% GERMINATION
DAYS
Nineleaf Lomatium
Sweetanise
G
% GERMINATION
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Yellow Sweetclover
Palmer Penstemon
Lewis Flax
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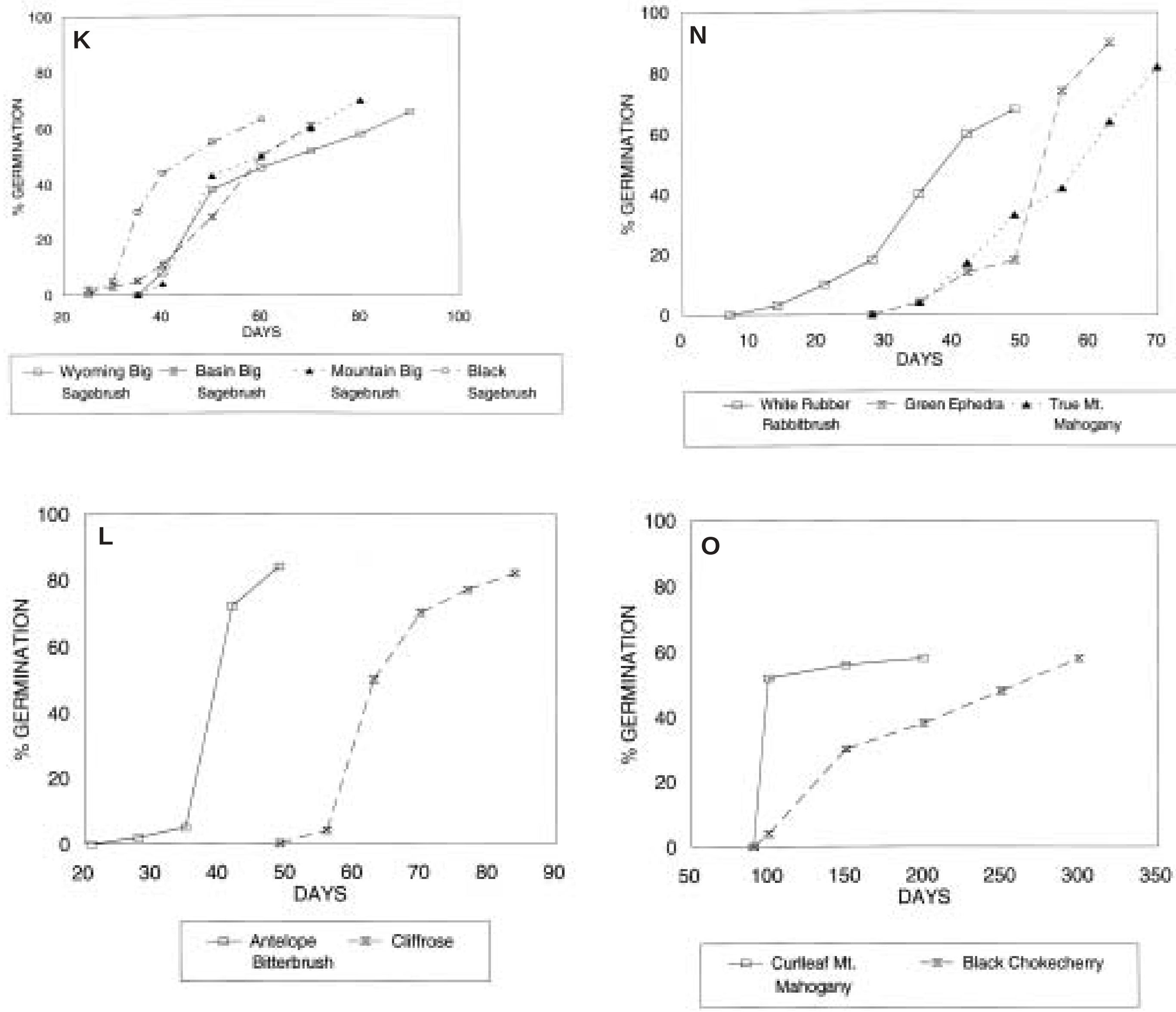
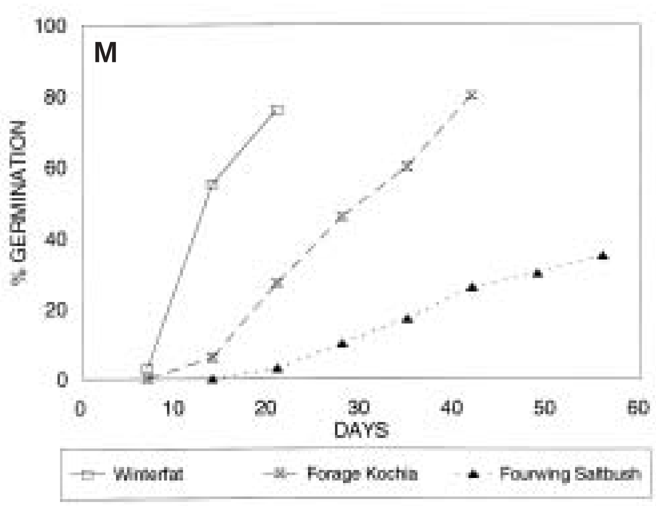
% GERMINATION
DAYS
Mountain Lupine
Silky Lupine

Figure 3 (Con.)





shrubs exhibit considerable seed dormancy. Time required for germination to occur varies between species and among accessions within a species (tables 1, 2, and 3; fig. 3) (Meyer and Monsen 1990; Meyer and others 1987, 1989; Stevens and Jorgensen 1994). Species that require more than 4 weeks to germinate should be fall-seeded to allow the seed sufficient time to overcome seed dormancy. This will also ensure that germination occurs at a time when the seedling can take full advantage of available seasonal soil moisture. Species exhibiting little dormancy can be spring-seeded if the date of seeding allows sufficient time for germination and seedling establishment prior to the usual soil drying experienced as the growing season progresses.

Longevity

The life span of seeds is affected by many variables such as: (1) the inherent nature of individual plant species; (2) condition of seed at harvest; (3) cleaning techniques; (4) storage conditions; (5) age of seed; (6) degree of infestation by disease organisms and insects; and (7) exposure to harmful chemicals. Fluctuating seed moisture content and high temperatures are especially damaging to seed longevity. Storing dried seed at low temperatures in vapor-tight containers will preserve seed viability for extended periods of time. Seed of forage kochia, dried to a 7 percent moisture content, and stored at room temperatures in airtight containers, have exhibited over 90 percent germination after 3 years. Undried seed stored at room temperature had only 14 percent germination after 3 years (Jorgensen and Davis 1984). In general, seed with hard coats and low water content are longer-lived, while seed with either relatively high water content, soft seedcoats, or both are shorter-lived (Quick 1961). There are exceptions to this generalization. Stevens and Jorgensen (1994) have reported on the longevity of many commonly used Intermountain species (tables 2, 3).

Location and Year of Production

Most species have a wide range of distribution, some larger than others. Populations of the same species growing under different climatic and edaphic conditions can exhibit different germination requirements.

Table 3—Percent germination of the same seed lots for grass, forb, and shrub seed the year of collection and following various years of storage in an open warehouse (Stevens and Jorgensen 1994).

	Years of storage											
Common names	**0**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
	Percent germination[a,b,c,d,e]											
Grasses												
Brome, smooth	91	94	0	0	0	0	0	0	0	0	0	0
Fescue, meadow	69*	0	+	0	99	0	0	0	0	0	0	0
Needle-and-thread	88	0	–	63	0	0	0	0	0	0	0	0
Ricegrass, Indian	55	0	0	0	0	0	63	0	0	0	0	0
Ricegrass, Indian	9*	0	+	0	0	0	0	0	0	0	49	0
Spike muhly	14*	0	+	62	0	0	0	0	0	0	0	0
Wheatgrass, tall	72*	0	+	0	0	91	0	0	0	0	0	0
Wheatgrass, tall	85	0	0	0	0	87	0	0	0	0	0	0
Wheatgrass, tall	85	0	0	0	0	92	0	0	0	0	0	0
Forbs												
Astragalus, giant	88	0	0	89	0	0	0	0	0	0	0	0
Crownvetch	41*	0	+	0	70	0	0	0	0	0	0	0
Goldeneye, showy	44	0	–	0	0	0	0	0	0	0	0	1
Goldeneye, showy	30*	0	+	0	0	0	75	0	0	0	0	0
Goldeneye, showy	39	0	–	0	0	0	0	0	0	0	0	0
Milkvetch, cicer	73	0	0	0	65	0	0	0	0	0	0	0
Milkvetch, cicer	51*	0	+	89	0	0	0	0	0	0	0	0
Penstemon, Eaton	63*	0	+	0	0	0	0	0	0	82	0	0
Penstemon, Eaton	71*	0	+	0	0	0	0	0	0	87	0	0
Penstemon, Palmer	89	0	0	0	0	0	0	0	0	82	0	0
Penstemon, thickleaf	74	0	0	0	0	0	0	0	0	0	68	0
Sweetanise	94	0	–	0	0	0	0	0	0	44	0	0
Shrubs												
Buffaloberry, silver	85	0	0	0	0	88	0	0	0	0	0	0
Honeysuckle	57	0	–	0	0	0	0	0	31	0	0	0
Indian apple	67	0	–	0	49	0	0	0	0	0	0	0
Indian apple	58	0	0	58	0	0	0	0	0	0	0	0
Oregon grape	25	0	0	0	0	0	0	0	0	23	0	0
Peashrub, Siberian	88	0	85	0	0	0	0	0	0	0	0	0

[a]Results based on two samples of 100 seeds, each at 100 percent purity.
[b]Asterisk (*) indicates significant afterripening.
[c]Plus sign (+) indicates significant increase in germination between germination years at the 0.05 level.
[d]Minus sign (–) indicates significant decrease in germination between germination years at the 0.05 level.
[e]Zero (0) indicates no data.

In work with rubber rabbitbrush, big sagebrush, and hopsage, clear relationships between collection site climate and seed germination patterns have been found (Meyer and Monsen 1990; Meyer and Pendleton 1990; Meyer and others 1987, 1989). Seed source should, therefore, be considered when purchasing seed. Seed from sources similar to that of the proposed planting site should be given preference over sources from locations having significantly different environmental conditions.

Often, germination percentage of a species from the same site will vary between years. Generally, percent germination is higher during years of high seed production than in years of poor seed production. Antelope bitterbrush collected in central Utah during high production years usually exhibits 95 percent or more germination, but during years of poor seed production the germination has varied from a low of 8 percent to a high of 68 percent.