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The timing of bud flush and bud set of the sub-boreal conifers *Abies sachalinensis*, *Picea jezoensis*, and *P. glehnii* dominant in Hokkaido, Japan

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北海道に優占する亜寒帯性針葉樹，トドマツ，アカエゾマツ，エゾマツの開芽期と冬芽形成期

後藤　晋

1. Introduction

In boreal or sub-boreal conifers, bud phenology is essential for regulating the growth period and avoiding frost damage (Aitken and Hannerz, 2001; Howe *et al*., 2003; Ogawa *et al*., 2010). Numerous data on bud phenology, including bud flush date and bud set date, are available for major forestry species, such as *Pinus sylvestris*, *Picea abies*, and *Pseudotsuga menziesii* distributed in boreal or sub-boreal forests of the Northern Hemisphere (Oleksyn *et al*., 1998; Aitken and Hannerz, 2001; Howe *et al*., 2003).

Three conifers, *Abies sachalinensis*, *Picea jezoensis*, and *P. glehnii*, dominate the natural forests in Hokkaido, northern Japan. Geographic or altitudinal variation of bud phenology has been reported in *A. sachalinensis* (Okada *et al*., 1970; Kurahashi and Hamaya, 1981), *P. jezoensis* (Kurahashi *et al*., 1996; Kisanuki and Kurahashi, 1999; Nakagawa *et al*., 2003), and *P. glehnii* (Okada, 1975; Kurahashi *et al*., 1996). In most previous studies, the observation of bud phenology was conducted only for a single species. Kurahashi *et al*. (1996) investigated the bud flush dates of *P. jezoensis*, *P. glehnii,* and a hybrid at the same site and found that the bud flush of *P. jezoensis* was apparently earlier than that of *P. glehnii,* whereas that of the hybrid was intermediate. However, the relationships between other species remain incompletely understood.

In the present study, the timing of bud flush and bud set were investigated for three conifers during the same season and the same site. Bud phenology and growth period were then characterized for each conifer by comparison among species.

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2. Materials and Methods

Plant materials

Cones of the three conifers were collected in 2011 from the University of Tokyo Hokkaido Forest (hereafter, UTHF), Graduate School of Agricultural and Life Sciences, The University of Tokyo. Cones of *A. sachalinensis* were collected from a seed orchard in compartment 72-A consisting of 16 clones selected throughout the UTHF. Cones of *P. glehnii* and *P. jezoensis* were collected from 13 and 11 mother trees naturally-distributed in compartment No. 10-B [800m above sea level (asl)] in the UTHF, respectively.

Seeds of each species were sown in the nursery at UTHF (43º13′ N, 142º23′ E, 230 m asl) on the 31th October, 2012. The seeds germinated during the spring of 2013 and grew during two growth seasons in the seed bed. The seedlings were then transplanted to another position within the nursery during mid-May 2015. During early April 2016, 30 seedlings per species were selected and identified by attaching plastic tags with individual ID numbers.

Phenology observation

Observation of phenology was conducted twice a week by visual inspection from the 26th April to 30th September in 2016. The phenology status was recorded as follows: (0) winter buds before bud flush, (1): bud flushing, (2): bud setting, (3): secondary flushing, and (4): bud set of secondary flushing. The dates (days of year, hereafter DOY; Table 1) of first bud flushing, bud setting, secondary flushing, and bud set of the secondary flushing were defined as “bud flush date,” “bud set date,” “second flush date,” and “second bud set date,” respectively. The growth period was calculated by subtracting the bud flush date from the bud set date. If secondary flushing occurred, the period was calculated by subtracting the second bud flush date from the second set date, and this period was added to the growth period for the diagnostic seedling.

Table 1. The relationship between calendar date and DOY (Days of Year) in 2016

Jan.		Feb.		Mar.		Apr.		May		June		July		Aug.		Sept.	
Date	DOY	Date	DOY	Date	DOY	Date	DOY	Date	DOY	Date	DOY	Date	DOY	Date	DOY	Date	DOY
1	1	1	32	1	61	1	92	1	122	1	153	1	183	1	214	1	245
2	2	2	33	2	62	2	93	2	123	2	154	2	184	2	215	2	246
3	3	3	34	3	63	3	94	3	124	3	155	3	185	3	216	3	247
4	4	4	35	4	64	4	95	4	125	4	156	4	186	4	217	4	248
5	5	5	36	5	65	5	96	5	126	5	157	5	187	5	218	5	249
6	6	6	37	6	66	6	97	6	127	6	158	6	188	6	219	6	250
7	7	7	38	7	67	7	98	7	128	7	159	7	189	7	220	7	251
8	8	8	39	8	68	8	99	8	129	8	160	8	190	8	221	8	252
9	9	9	40	9	69	9	100	9	130	9	161	9	191	9	222	9	253
10	10	10	41	10	70	10	101	10	131	10	162	10	192	10	223	10	254
11	11	11	42	11	71	11	102	11	132	11	163	11	193	11	224	11	255
12	12	12	43	12	72	12	103	12	133	12	164	12	194	12	225	12	256
13	13	13	44	13	73	13	104	13	134	13	165	13	195	13	226	13	257
14	14	14	45	14	74	14	105	14	135	14	166	14	196	14	227	14	258
15	15	15	46	15	75	15	106	15	136	15	167	15	197	15	228	15	259
16	16	16	47	16	76	16	107	16	137	16	168	16	198	16	229	16	260
17	17	17	48	17	77	17	108	17	138	17	169	17	199	17	230	17	261
18	18	18	49	18	78	18	109	18	139	18	170	18	200	18	231	18	262
19	19	19	50	19	79	19	110	19	140	19	171	19	201	19	232	19	263
20	20	20	51	20	80	20	111	20	141	20	172	20	202	20	233	20	264
21	21	21	52	21	81	21	112	21	142	21	173	21	203	21	234	21	265
22	22	22	53	22	82	22	113	22	143	22	174	22	204	22	235	22	266
23	23	23	54	23	83	23	114	23	144	23	175	23	205	23	236	23	267
24	24	24	55	24	84	24	115	24	145	24	176	24	206	24	237	24	268
25	25	25	56	25	85	25	116	25	146	25	177	25	207	25	238	25	269
26	26	26	57	26	86	26	117	26	147	26	178	26	208	26	239	26	270
27	27	27	58	27	87	27	118	27	148	27	179	27	209	27	240	27	271
28	28	28	59	28	88	28	119	28	149	28	180	28	210	28	241	28	272
29	29	29	60	29	89	29	120	29	150	29	181	29	211	29	242	29	273
30	30			30	90	30	121	30	151	30	182	30	212	30	243	30	274
31	31			31	91			31	152			31	213	31	244		

3. Results and Discussion

Terminal buds were damaged in one and four seedlings in *A. sachalinensis* and *P. jezoensis*, respectively. Furthermore, the bud flush date of one seedling in *P. jezoensis* could not be identified due to human error. Then, the numbers of seedlings observed for *A. sachalinensis*, *P. glehnii*, and *P. jezoensis* were 29, 30, and 24, respectively (Table 2), the medians of their bud flush dates were 141, 145, and 127, respectively, and the medians of their bud set dates were 166, 189, and 157, respectively. Bud flush date and bud set date of *P. jezoensis* were clearly earlier than those of *A. sachalinensis* and *P. glehnii* (Table 2; Fig. 1). The width of the distribution peak for bud set date in *A. sachalinensis* was narrow, whereas that in *P. glehnii* was wide (Fig. 1). No seedlings exhibited second flushing in *A.sachalinensis* (Table 3). In contrast, one seedling and three seedlings exhibited second flushing in *P. glehnii* and *P. jezoensis*, respectively (Tables 4 and 5). The medians of the growth periods in *A. sachalinensis*, *P. glehnii*, and *P. jezoensis* were 24, 45, and 30, respectively.

Table 2. Statistics of bud flush date, bud set date and growth period in three conifers, *Abies sachalinensis*, *P. glehnii*, and *P. jezoensis*

Phenology	*A. sachalinensis* (n = 29)		*P. glehnii* (n = 30)		*P. jezoensis* (n = 24)	
	Mean	Range	Mean	Range	Mean	Range
Bud flush	142 (5/21)	138-152	143 (5/22)	138-148	130 (5/8)	127-138
Bud set	166 (6/14)	162-173	194 (7/12)	180-232	159 (6/7)	152-173
Growth period	24	17-32	51	35-87	31	17-49

DOY and calendar date in parenthesis are shown.

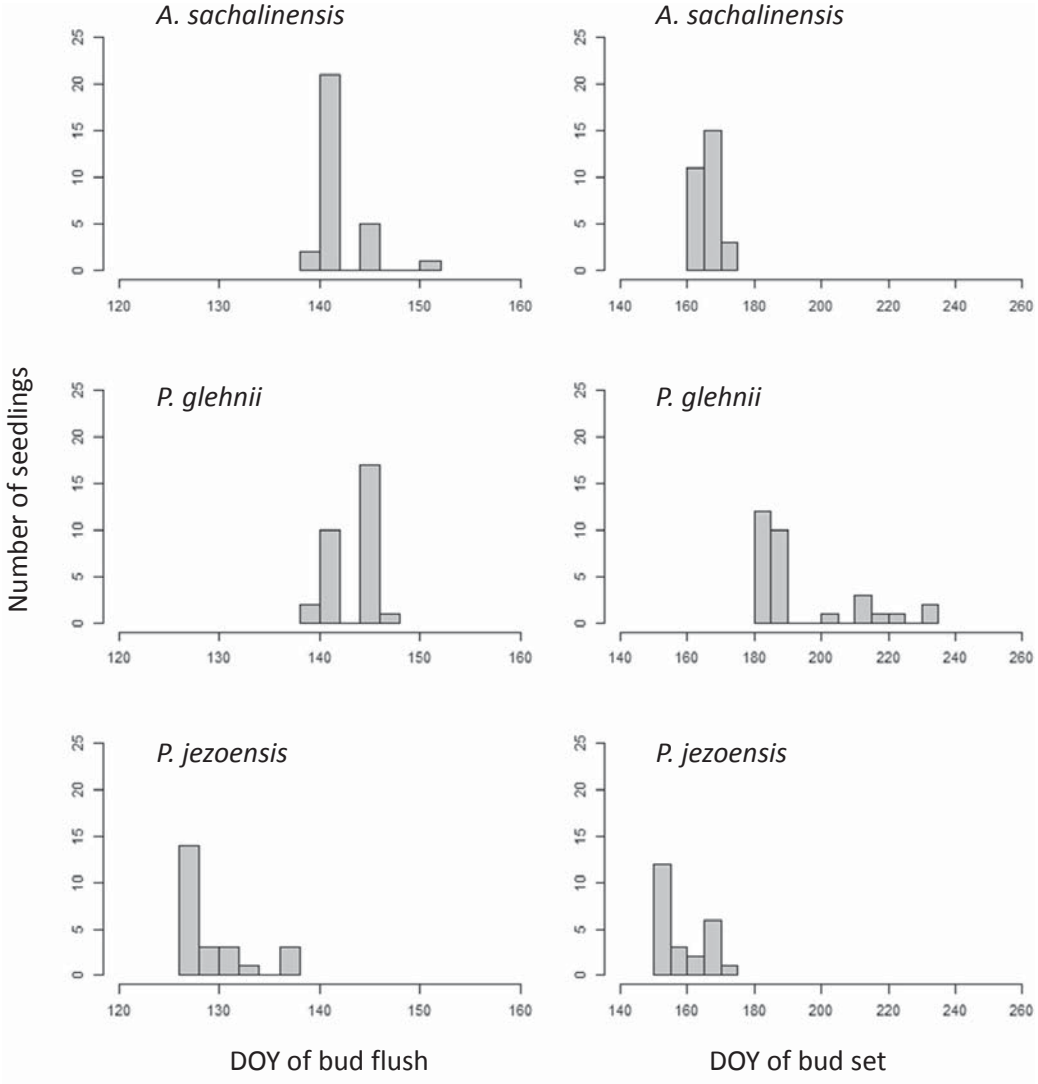

Fig.1. DOY (Days of year) of bud flush and bud set for three sub-boreal conifers

Table 3. Phenological data for *Abies sachalinensis*

ID/DOY	120	123	127	130	131	134	138	141	145	148	152	155	159	162	166	169	173	176	180	183	187	190	194	197	201	204	208	215	218	222	225	232	236	239	243	246	253	260	267	271	274
As01	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
As02	0	0	0	0	0	0	0	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
As03	0	0	0	0	0	0	0	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
As04	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
As06	0	0	0	0	0	0	0	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
As07	0	0	0	0	0	0	0	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
As08	0	0	0	0	0	0	0	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
As09	0	0	0	0	0	0	0	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
As10	0	0	0	0	0	0	0	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
As11	0	0	0	0	0	0	0	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
As12	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
As13	0	0	0	0	0	0	0	0	0	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
As14	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
As15	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
As16	0	0	0	0	0	0	0	0	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
As17	0	0	0	0	0	0	0	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
As18	0	0	0	0	0	0	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
As19	0	0	0	0	0	0	0	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
As20	0	0	0	0	0	0	0	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
As21	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
As22	0	0	0	0	0	0	0	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
As23	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
As24	0	0	0	0	0	0	0	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
As25	0	0	0	0	0	0	0	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
As26	0	0	0	0	0	0	0	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
As27	0	0	0	0	0	0	0	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
As28	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
As29	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
As30	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2

0: winter bud, 1: bud flushing, 2: bud set, 3: second flushing, 4: bud set of second flushing, As05: terminal bud was damaged.

Table 4. Phenological data for *Picea glehnii*

ID/DOY	120	123	127	130	131	134	138	141	145	148	152	155	159	162	166	169	173	176	180	183	187	190	194	197	201	204	208	215	218	222	225	232	236	239	243	246	253	260	267	271	274
Pg01	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pg02	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pg03	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pg04	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pg05	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pg06	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pg07	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pg08	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Pg09	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pg10	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pg11	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2
Pg12	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pg13	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2
Pg14	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pg15	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pg16	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pg17	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pg18	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pg19	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pg20	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pg21	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2
Pg22	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2
Pg23	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pg24	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pg25	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pg26	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pg27	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pg28	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pg29	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pg30	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2

0: winter bud, 1: bud flushing, 2: bud set, 3: second flushing, 4: bud set of second flushing

Table 5. Phenological data for *Picea jezoensis*

ID/DOY	120	123	127	130	131	134	138	141	145	148	152	155	159	162	166	169	173	176	180	183	187	190	194	197	201	204	208	215	218	222	225	232	236	239	243	246	253	260	267	271	274
Pj01	0	0	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pj02	0	0	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Pj03	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pj04	0	0	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pj05	0	0	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pj06	0	0	0	0	0	0	0	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pj07	0	0	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pj09	0	0	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Pj11	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pj13	0	0	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pj14	0	0	0	0	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pj15	0	0	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pj17	0	0	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pj18	0	0	0	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pj19	0	0	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pj21	0	0	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pj23	0	0	0	0	0	0	0	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pj24	0	0	0	0	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pj25	0	0	0	0	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pj26	0	0	0	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pj27	0	0	0	0	0	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pj28	0	0	0	0	0	0	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pj29	0	0	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pj30	0	0	0	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4

0: winter bud, 1: bud flushing, 2: bud set, 3: second flushing, 4: bud set of second flushing, Pj08, Pj10, Pj16, Pj20, Pj22: terminal bud was damaged. P12: the bud flush date for this seedling could not be identified.

The bud flush dates of *A. sachalinensis*, *P. glehnii*, and *P. jezoensis* observed in the present study were consistent with those identified in previous studies conducted in the same site (Kurahashi and Hamaya, 1981; Kurahashi *et al*., 1996; Kisanuki and Kurahashi, 1999). Data for timing of bud flush of these species were relatively abundant, whereas that of bud set were scarce. At the same site, Kurahashi and Hamaya (1981) investigated the timing of bud sets of seedlings of *A. sachalinensis* derived from different altitudes and found that the bud set ranged from the 9th to 12th July. The bud set date of *A. sachalinensis* obtained in the present study was approximately one month earlier than that of the previous study. The bud phenology significantly varied depending on the observed year (Kisanuki and Kurahashi, 1999). Therefore, bud set date should be evaluated by observation in several years in future studies.

4. Conclusion

The present study clearly demonstrated the difference in bud phenology among three conifers. *P. jezoensis* is characterized by earlier bud flush date and earlier bud set date (approximately three weeks earlier than those of the other two conifers). *P. glehnii* is characterized by mid-term bud flush date and the latest bud set date to maintain a long growth period. The relationship between *P. glehnii* and *P. jezoensis* in regards to bud flush date is consistent with findings of the previous study (Kurahashi *et al*., 1996). *A. sachalinensis* is characterized by mid-term bud flush date and mid-term bud set date, and the width of the distribution peak of the bud set was narrow. These differences in bud phenology suggest that a strategy to maintain the growth period and to avoid frost damage should be dependent on species.

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