Chapter 5
Acer Tree Species

Masako Kubo, Hitoshi Sakio, Motohiro Kawanishi, and Motoki Higa

Abstract Thirteen *Acer* species were found in Ooyamazawa riparian forest in Japan. Of these, the shrubby species *A. carpinifolium* and *A. argutum* and the tall tree species *A. shirasawanum* and *A. mono* were the most abundant. Sprouts of shrubby species were common, but not of tall tree species, which implies that individuals of shrubby species are maintained in the understory layer via sprouts, whereas tall tree species extend upward toward the canopy. All four *Acer* species were found mainly on upstream sediments; moreover, the density of *A. shirasawanum* was high, implying that *A. shirasawanum* may eventually become an important species in the sedimentary upstream area. On the other hand, *A. carpinifolium* was dominant in the unstable downstream V-shaped valley; this species adapts to the disturbed downstream area by producing more sprouts. These differences in life history promote diversity in the forest structure of Ooyamazawa riparian forest.

Keywords *Acer argutum* · *Acer carpinifolium* · *Acer pictim* · *Acer shirasawanum* · Distribution · Riparian forest · Sprouting traits

M. Kubo (✉)
Faculty of Life and Environmental Science, Shimane University, Shimane, Japan
e-mail: kubom@life.shimane-u.ac.jp

H. Sakio
Sado Island Center for Ecological Sustainability, Niigata University, Niigata, Japan
e-mail: sakio@agr.niigata-u.ac.jp; sakiohit@gmail.com

M. Kawanishi
Faculty of Education, Kagoshima University, Kagoshima, Japan
e-mail: kawanishi@edu.kagoshima-u.ac.jp

M. Higa
Faculty of Science and Technology, Kochi University, Kochi, Japan
e-mail: mhiga@kochi-u.ac.jp

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5.1 Introduction

The genus *Acer* is comprised of tree species that play important roles in forests across the Northern Hemisphere, particularly in late-successional forests dominated by hardwoods such as beech (*Fagus*) species (Runkle 1990; Poulson and Platt 1996; Cao and Ohkubo 1999). *Acer* species often coexist with other deciduous species, depending on light conditions and/or disturbance regimes (Sipe and Bazzaz 1995). Some *Acer* species are found in riparian forests (Ohno 2008), in topographical habitats created by various types of disturbance (Masaki et al. 1992, 2005; Suzuki et al. 2002), suggesting that some *Acer* species may exhibit pioneer traits.

In Japan, 28 *Acer* tree species are distributed throughout sub-tropical, warm-temperate, cool-temperate, and sub-alpine forests (Yonekura 2012). Many trees in riparian forests of the cool-temperate zone in Japan are *Acer* species (Ohno 2008). *Acer* is therefore an important taxonomic group that contributes to tree species diversity and forest structure in these riparian forests. *Acer* species typically coexist with other tree species due to their different life histories (Sakio et al. 2002), and represent both early successional species, in response to various riparian disturbances, and late-successional species, which play important roles in riparian forest dynamics.

Acer carpinifolium Siebold et Zucc., *Acer shirasawanum* Koidz., *Acer pictum* Thunb., *Acer argutum* Maxim., *Acer nipponicum* H.Hara, *Acer rufinerve* Siebold et Zucc., *Acer tenuifolium* (Koidz.) Koidz., *Acer palmatum* Thunb., *Acer amoenum* Carrière var. *amoenum*, *Acer maximowiczianum* Miq., *Acer cissifolium* (Siebold et Zucc.) K.Koch, *Acer distylum* Siebold et Zucc., and *Acer micranthum* Siebold et Zucc. all grow in the Ooyamazawa riparian area of central Japan, and the four dominant *Acer* species are *Acer carpinifolium*, *A. shirasawanum*, *A. pictim*, and *A. argutum*. In this chapter, we clarify the life histories of these four major *Acer* species and discuss the relationship between their life histories and riparian topography in Ooyamazawa.

5.2 Study Species

A. carpinifolium, *A. shirasawanum*, *A. pictim*, and *A. argutum* are indigenous to Japan. *A. carpinifolium* and *A. pictim* are distributed in Honshu, Shikoku, and Kyusyu Islands, and *A. shirasawanum* and *A. argutum* are distributed in Honshu and Shikoku Islands. *A. carpinifolium* and *A. argutum* generally grow to shrub height (Table 5.1, Fig. 5.1). These four *Acer* species are deciduous and monophyllous; *A. carpinifolium* has oval leaves, whereas the remaining three *Acer* species have palmate leaves.

A. carpinifolium is a dioecious shrub that grows to a height of approximately 10 m and produces shoots around stems. This species is mainly distributed in riparian areas in the mountains, flowering in May and producing seeds during

Table 5.1 Traits of four *Acer* tree species found in Ooyamazawa

	A. carpinifolium	*A. shirasawanum*	*A. pictim*	*A. argutum*
				
Tree height	Shrubby	Tall	Tall	Shrubby
Sexual expression	Dioecy	Monoecy	Monoecy	Dioecy
Flower season	May	May	May	May
Fruit season	Sep.–Oct.	Sep.–Oct.	Sep.–Oct.	Sep.–Oct.
Sprout	Around stem	Few	Few	Around stem and root sucker

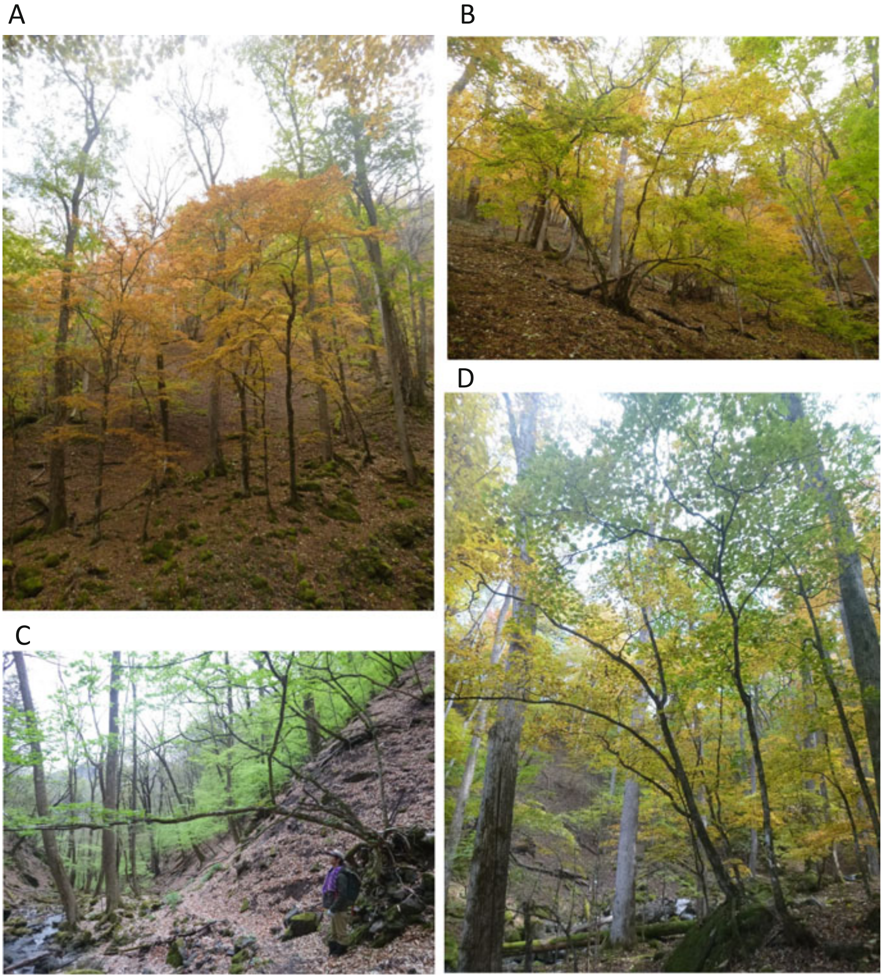

Fig. 5.1 Tree form of the four most common *Acer* species in the Ooyamazawa riparian site. (**a**) *A. shirasawanum* in the subcanopy layer. (**b**) *A. carpinifolium* in the shrub layer. (**c**) *A. argutum* in the shrub layer. (**d**) *A. pictim* in the subcanopy layer

September–October. *A. shirasawanum* is a monoecious tree that grows to a height of about 20 m and diameter at breast height (DBH) of 30–40 cm, with larger individuals reaching a DBH of 80 cm. *A. shirasawanum* is mainly found in mountain areas; it flowers in May and produces seeds during September–October. *A. pictim* is a monoecious tree that grows to a height of 20 m and DBH of 50–60 cm; it is found in riparian and mountain areas, flowers in May, and produces seeds during September–October. *A. argutum* is a dioecious shrub that grows to a height of about 8 m and produces shoots close to the root system; it is found in riparian and mountain areas, flowers in May, and produces seeds during September–October.

5.3 Structure and Distribution

5.3.1 Abundance and Structure of Four Acer *Species*

In this study, we identified 1204 individual trees (255.4 trees/ha) of 13 *Acer* species in a 4.71-ha plot within the Ooyamazawa riparian forest (Table 5.2, Fig. 5.2). Thus, Ooyamazawa contains roughly half of the 28 *Acer* species found in Japan (Yonekura 2012). *Acer* species comprised 28.9% of a total of 45 tree species and 57.0% of a total of 2111 individuals (448.1/ha) in the study area. Together, *A. carpinifolium*, *A. shirasawanum*, *A. pictum*, and *A. argutum* comprised 96.3% of all *Acer* individuals and 55.0% of all individual trees.

Acer species densities were particularly high in the subcanopy and shrub layers (Table 5.2, Fig. 5.3). *A. carpinifolium* and *A. argutum* were found in both the subcanopy and shrub layers; however, the vast majority of individuals were found in the shrub layer. In contrast, *A. shirasawanum* and *A. pictum* were found in all layers, with most individuals in the subcanopy and shrub layers.

Small *Acer* individuals (DBH $<$ 40 cm) were numerous; most individual *A. carpinifolium* and *A. argutum* shrubs did not exceed a DBH of 20 cm (Fig. 5.4). *A. pictum* had the largest DBH at 92.0 cm, followed by *A. shirasawanum* at 62.8 cm (Table 5.2).

5.3.2 Spatial Distribution of Four Acer *Species*

The four *Acer* species were mainly distributed on upstream sedimentary debris flows; among these, only *A. carpinifolium* was also dominant in the downstream V-shaped valley (Fig. 5.5). We divided the study plot into 20 subplots along the stream and compared the densities of the four *Acer* species and the dominant canopy tree *Fraxinus platypoda* in the canopy, subcanopy, and shrub layers in each subplot (Fig. 5.6). In the subcanopy layer, *A. carpinifolium* density was higher in the downstream valley (Wilcoxon rank sum test, $P < 0.01$), although in the shrub layer *A. carpinifolium* density was high both upstream and downstream (Wilcoxon rank sum test, $P = 0.16$). In the subcanopy layer, *A. argutum* density was low, while in the shrub layer, *A. argutum* density was significantly higher upstream than downstream in the valley (Wilcoxon rank sum test, $P < 0.01$). In both the subcanopy and shrub layers, *A. shirasawanum* density was higher upstream (Wilcoxon rank-sum test, $P < 0.01$), as was *A. pictum* density in the shrub layer (Wilcoxon rank sum test, $P < 0.01$), although *A. pictum* densities in the canopy and subcanopy layers did not differ significantly between upstream and downstream areas (Wilcoxon rank sum test, canopy layer; $P = 0.28$, subcanopy layer; $P = 0.12$).

The sedimentary upstream area was the best habitat for three of the four *Acer* species, whereas *A. carpinifolium* was better suited to the downstream valley (Fig. 5.5). The upstream alluvial fan and terrace debris flows contain rich soil and

Table 5.2 Tree density of each *Acer* species found in Ooyamazawa

		Number(/ha)					
	Number (/ ha)	Canopy	Subcanopy	Shrub	Maximum DBH (cm)	Mean DBH (cm)	Mean number of shoot stems
A. carpinifolium	92.1	–	5.1	87.0	22.0	8.0 ± 3.2	6.0 ± 4.3
A. shirasawanum	78.5	0.4	27.0	51.2	62.8	13.2 ± 8.7	0.2 ± 0.6
A. pictim	57.1	2.8	20.8	33.5	92.0	13.3 ± 10.7	0.1 ± 0.4
A. argutum	18.5	–	0.4	18.0	13.2	6.4 ± 2.2	5.3 ± 4.1
A. nipponicum	2.5	0.2	0.6	1.7	28.7	10.0 ± 7.3	2.1 ± 2.5
A. rufinerve	2.3	0.2	1.1	1.1	33.6	12.1 ± 7.6	0.2 ± 0.4
A. tenuifolium	1.5	–	0.4	1.1	15.0	8.1 ± 3.0	0.4 ± 0.7
A. palmatum	1.3	–	0.6	0.6	23.9	14.1 ± 6.1	0.0
A. amoenum var. *moenum*	0.6	–	0.6	–	15.5	11.2 ± 3.2	0.0
A. maximowiczianum	0.4	–	0.4	–	39.0	28.1 ± 11.0	0.5 ± 0.5
A. cissifolium	0.2	–	0.2	–	18.2	18.2	3.0
A. distylum	0.2	–	0.2	–	14.0	14.0	2.0
A. micranthum	0.2	–	–	0.2	4.1	4.1	1.0
Acer species	255.4	3.6	57.5	194.5	92.0	10.8 ± 7.9	2.7 ± 4.0
Total species	448.1	104.0	99.6	244.6	153.4	21.4 ± 22.4	2.0 ± 4.1

Values are means ± standard deviation (SD) for each species. *DBH* Diameter at breast height

Fig. 5.2 *Acer* species found in the Ooyamazawa riparian site. (**a**) *A. carpinifolium*. (**b**) *A. shirasawanum*. (**c**) *A. pictim*. (**d**) *A. argutum*. (**e**) *A. nipponicum*. (**f**) *A. rufinerve*. (**g**) *A. tenuifolium*. (**h**) *A. palmatum*. (**i**) *A. amoenum* var. *amoenum*. (**j**) *A. maximowiczianum*. (**k**) *A. cissifolium* (photo by Takuto Shitara). (**l**) *A. distylum*. (**m**) *A. micranthum*

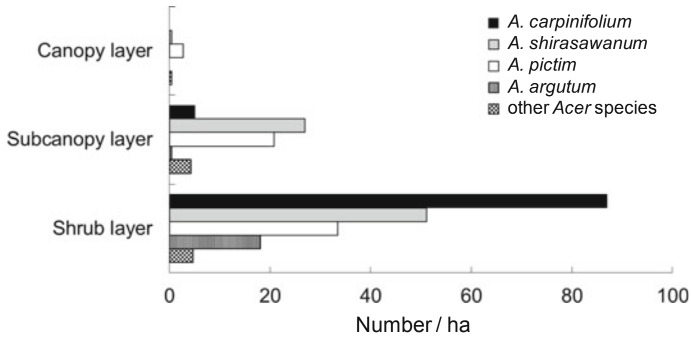

Fig. 5.3 Tree density among *Acer* species for each layer. Trees in the canopy layer reach the canopy and exceed a height of 20 m and DBH of 20 cm. Trees in the subcanopy layer do not reach the canopy and are <20 m high. Trees in the shrub layer are <10 m high

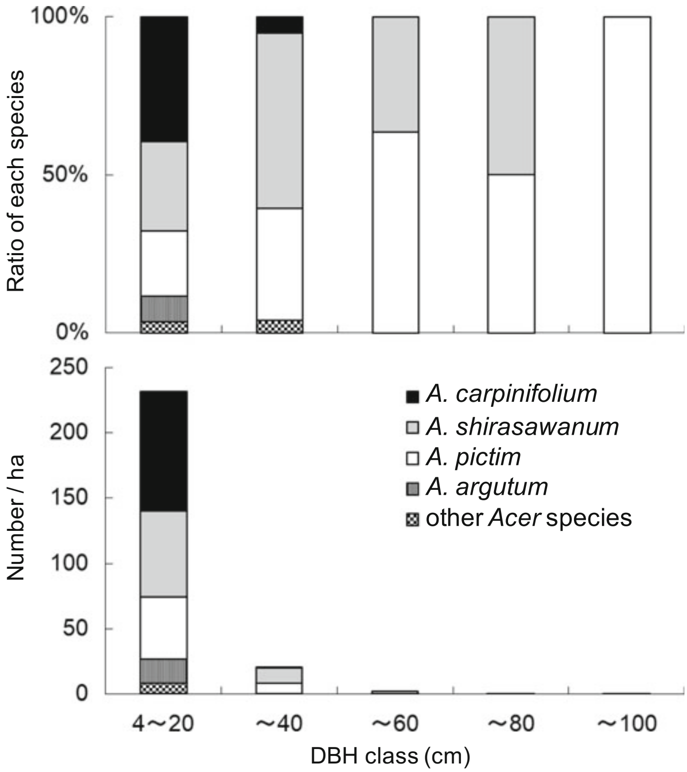

Fig. 5.4 DBH class distribution of *Acer* species. Upper, DBH ratio for each *Acer* species; lower, DBH frequency distribution for *Acer* species

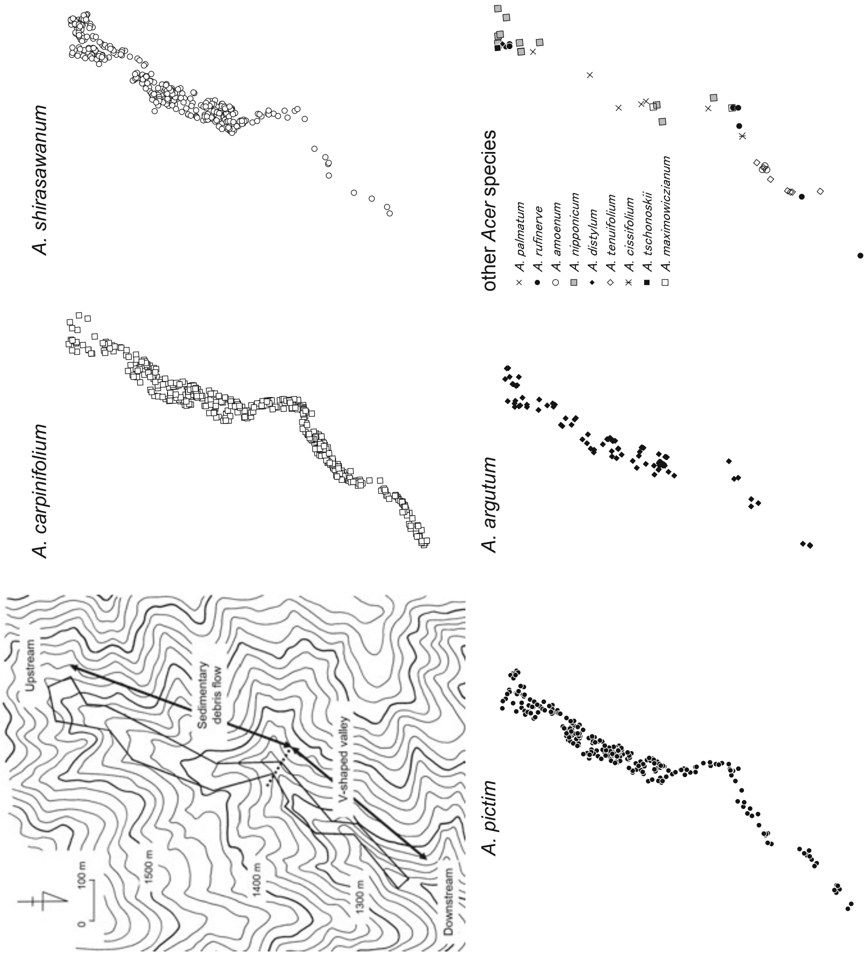

Fig. 5.5 Distribution of *Acer* trees at the Ooyamazawa riparian site

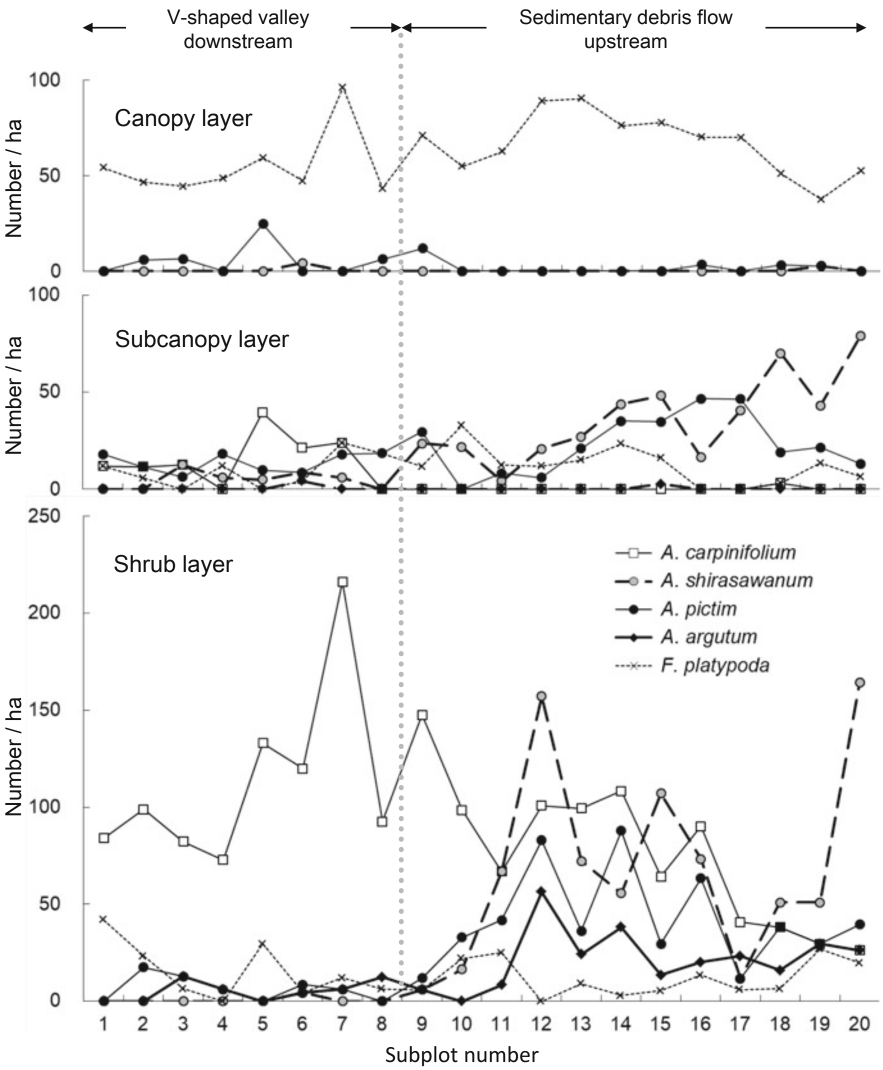

Fig. 5.6 Density of the four most common *Acer* species and *Fraxinus platypoda*. The study plot was divided into 20 subplots at 60-m intervals along the stream, with eight subplots (1–8) in the downstream V-shaped valley and 12 subplots (9–20) in the upstream sedimentary debris flow. Upper, tree density in the canopy layer; middle, tree density in the subcanopy layer; lower, tree density in the shrub layer

a considerable litter layer; in contrast, little litter is found on terrace scarps, new landslide sites, old landslide slopes, or talus of the downstream V-shaped valley (Kawanishi et al. 2004). Downstream disturbances including erosion and sedimentation of soil, sand, and/or gravel are frequent due to stream flow and/or steep slopes.

Fewer disturbances occur upstream where slopes are gentle (about 12°) and the valley bottom has been filled by large landslides and/or debris flows.

Factors determining the distribution patterns of *Acer* species can include shade tolerance, the distance from the seed source, and germination site conditions, e.g., areas of soil and litter accumulation. Leaf litter cover also reduces the risk of predation on *Acer* seeds (Tanaka 1995). Although *A. pictum* was found in the canopy and subcanopy layers both upstream and downstream, *A. shirasawanum* clearly occurs in the subcanopy and shrub layers only upstream, where it is dominant (Figs. 5.5 and 5.6). *A. pictum* saplings can survive even in the forest understory (Abe et al. 1995; Hara 1987; Masaki et al. 1992) by acclimating to deep shade (Kitao et al. 2006). *A. shirasawanum* can regenerate in smaller gaps than *A. pictum*, due to its shade tolerance (Sakai 1986). It remains unclear why the range of *A. shirasawanum* does not extend downstream, since its shade tolerance should allow it to dominate the more stable upstream sediments, where soils are rich, litter accumulation is greater, and the upland forest is a nearby seed source. For these reasons, *A. shirasawanum* may eventually become an important species in the sedimentary upstream area.

5.4 Sprouting Traits

The two *Acer* shrub species, *A. carpinifolium* and *A. argutum*, produced large numbers of shoots (Fig. 5.7). Among *Acer* species, the greatest mean number of shoots was observed in *A. carpinifolium* (6.0 ± 4.3), exceeded only by *Cercidiphyllum japonicum* (9.0 ± 12.1) in the Ooyamazawa study site (Chap. 4). *A. shirasawanum* and *A. pictum*, both of which are tall tree species, had fewer shoots, suggesting that *A. carpinifolium* and *A. argutum* may reproduce in the shrub layer via sprouting.

Shrub species tend to produce many shoots (Midgley 1996); reproduction via sprouting provides an advantage in habitats where environmental conditions are severe (Sakai et al. 1995; Kubo et al. 2010). The low light conditions in the shrub layer prevent *A. carpinifolium* and *A. argutum* from consistently receiving direct light. Main shoots tend to die when they grow too large to balance photosynthesis and respiration, allowing a large shoot with large leaf area to become a new main shoot.

The large numbers of shoots observed in the shrub *A. carpinifolium* are therefore suitable for habitats with significant surface erosion, allowing long-term survival of some individuals in the subcanopy layer within the downstream V-shaped valley, where the density of other *Acer* species is low (Figs. 5.5 and 5.6). Similarly, *Euptelea polyandra* has shoots adapted to its unstable habitat conditions (Sakai et al. 1995), with main shoots gradually inclining as they increase in size, facilitating the establishment of younger shoots. The large number of shoots and dominance of *A. carpinifolium* in the unstable V-shaped valley suggest that this species has sprouting traits adapted to the unstable steep slopes and disturbance regime of this site.

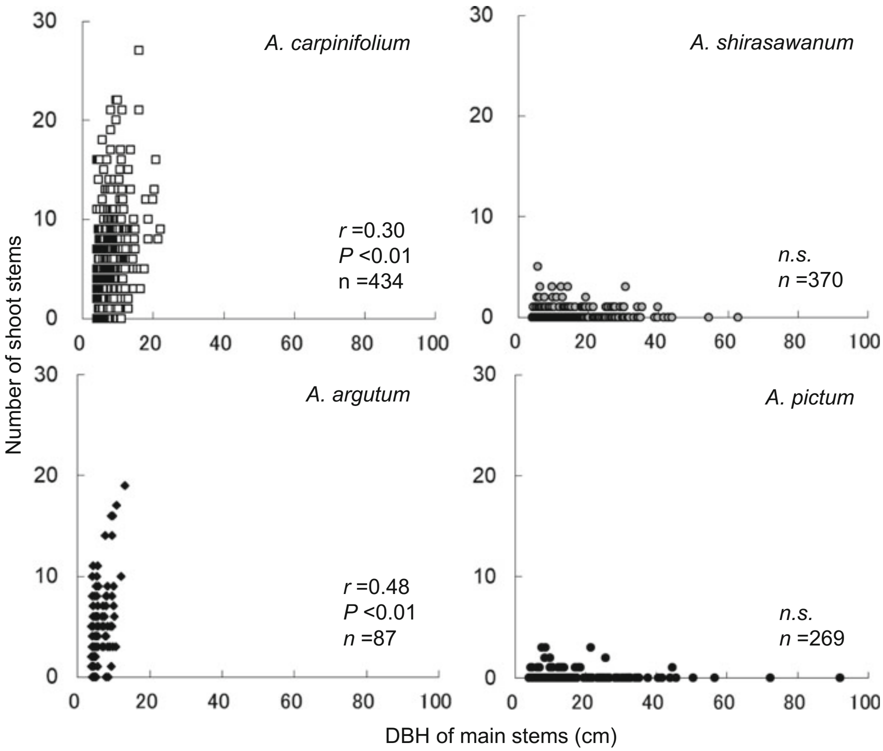

Fig. 5.7 Relationship between shoot number and DBH in the four most common *Acer* species

Some species reproduce via spontaneous sprouting (Verwijst 1988; Keeley 1992). In this study, almost all *A. argutum* were found on stable upstream sediments. Many *A. argutum* shoots are produced near the soil around the main stem, like root suckers, whereas *A. carpinifolium*, which was dominant in the unstable V-shaped valley, sprouts from the shoot base. Some tree species extend their roots to the surface to produce new shoots (Gyokusen et al. 1991; Ogawa et al. 1999; Sakio 2015). Therefore *A. argutum* reproduces through sprouting in the shrub layer on stable upstream sediments, where soil is rich, and its range does not extend to the V-shaped valley, where slopes are steep and soil is poor.

5.5 Conclusion

In this study, we identified 13 *Acer* tree species in a 4.71-ha study plot in the Ooyamazawa riparian forest. Among these, four species, *A. carpinifolium*, *A. shirasawanum*, *A. pictum*, and *A. argutum* constituted 55.0% of all individuals. These four coexisting *Acer* species had different life history characteristics in terms of size, distribution, and shoot production. *A. shirasawanum* and *A. pictum* are tall tree species, whereas *A. carpinifolium* and *A. argutum* are shrub species (Table 5.2, Fig. 5.3), which produce more shoots than the taller species (Fig. 5.7). All four *Acer* species were mainly found on upstream sediments. However, *A. shirasawanum* and *A. argutum* were distributed only on stable upstream sediments, *A. pictum* was distributed in the canopy and subcanopy layers in both areas, and *A. carpinifolium* was dominant in the unstable downstream V-shaped valley (Figs. 5.5 and 5.6). The two shrub species have different sprouting traits, with *A. carpinifolium* adapting to the disturbed downstream area by producing more shoots and *A. argutum* producing a lot of shoots upstream, where the soil is rich and disturbance occurs less frequently. These differences in life history promote diversity in forest structure in this riparian forest.

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