Recent Naturalization of *Tragopogon* species (Asteraceae) In Kami-ina Region of Nagano Prefecture

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上伊那地方におけるバラモンジン属植物の帰化について

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要旨：近年，長野県上伊那地方では，バラモンギク属植物（キク科）の帰化が急速に目立つようになった。そこで本研究では，バラモンギク属植物が帰化・定着したとみられる上伊那地方4地点（辰野，箕輪，南箕輪，伊那）において植生調査を行い，種の同定を行うとともに，開花・結実の状況や群落の種組成の把握を試みた。その結果，4 地点で確認されたのは，フトエバラモンギク（*Tragopogon dubius*）1種のみであった。いずれの地点でも開花・結実が認められ，細い根出葉を叢生する越冬期の草型も確認された。生育地は開けた裸地（路傍）や緑化された斜面に発達した草本群落（土手や河川堤防）であった。出現種数に占める帰化植物種数の割合は42～68%と高く，最も早期に帰化の見られた地点（辰野）から離れるほどこの割合は高くなる傾向にあった。起源地は不明ながら，本種の種子は大きな冠毛を有するため，風による種子散布で侵入してきたものと推測される。

キーワード：帰化，フトエバラモンギク，上伊那地方
Keywords: Naturalization, *Tragopogon dubius*, Kami-ina region

Introduction

Salsify (*Tragopogon porrifolius*) is a traditional biennial root crop of Asteraceae in Europe (Inden, 1989; Pardo-de-Santayana *et al*., 2006), and is also known as ‘oyster plant’ or ‘vegetable oyster’. However, salsify and related species are also known as escape weeds in Europe (Inden, 1989), and are considered to be invasive weeds in Canada (Upadhyaya *et al*. 1993; Qi *et al*. 1996) and the United States (Ziska, *et al*. 2011).

In Japan, salsify was introduced early in the Meiji period (latter half of the 19th century) as a food crop named ‘baramonzin’ in Japanese, and was raised experimentally by some public institutions, such as governmental breeding stations and botanical gardens of the Imperial University (Tamura, 1968). However, the cultivation remained limited thereafter, and it became generally known as an ornamental plant rather than an edible crop. Some species of salsify have escaped to establish themselves as naturalized plants at present. *Tragopogon* is not an indigenous genus in Japan, and the taxonomy of naturalized *Tragopogon* species is somewhat confusing: Makino

and Nemoto (1931) reported two species of salsify (*T. porrifolius* and *T. pratensis*) as domesticated plants, without the mention of naturalization. No species were listed as clearly naturalized non-native species until around 1970 (Kasahara, 1968; Osada, 1972), one species (*T. porrifolius*) was listed with a brief mention of *T. pratensis* (Osada, 1976), two species (*T. porrifolius* and *T. pratensis*) were listed in around 2000 (Shimizu, 1997; Shimizu 2003), and the existence of another species (*T. dubius*), having been mistaken for *T. pratensis*, was identified later (Tachikake and Nakamura, 2007).

In Nagano Prefecture, Central Japan, two naturalized *Tragopogon* species (*T. porrifolius* and *T. pratensis*) were sporadically recorded in the northern and eastern parts (Shimizu, 1997), probably with the mistaken identification of *T. pratensis* going unnoticed. In the Kami-ina region, *Tragopogon* species could be seen in only a limited area as ornamental plants until several years ago. However, in recent years, we recognized the escape of *Tragopogon* species into roadside or levee vegetation; whether this is a sign of naturalization or not, rapid expansion of distribution range by wind-dependent seed dispersal would follow the success of seed reproduction.

Despite the great species diversity in Asteraceae, there are only two major food crops, sunflower and lettuce. The rareness of major domesticated species in this family is chiefly attributed to the prevalence of secondary defense compounds, the lack of carbohydrates that can be digested by humans and wind-dependent seed dispersal (Dempewolf *et al*., 2008). In contrast, these persevering and dispersible properties will promote the naturalization of the species beyond native regions, and many Asteraceae species (e.g. *Ambrosia*, *Bidens*, *Conyza*, *Erigeron*, *Gnaphalium*, *Rudbeckia*, *Solidago*, *Taraxacum*) have been naturalized to date all over Japan (Shimizu, 2003). With regard to salsify (*Tragopogon*), seeds with large pappus accelerate the rapid and wide expansion by wind. In addition, they have linear leaves like Poaceae grass (Inden, 1989), which enables them to escape weeding if they sprout in Poaceae-dominant fields.

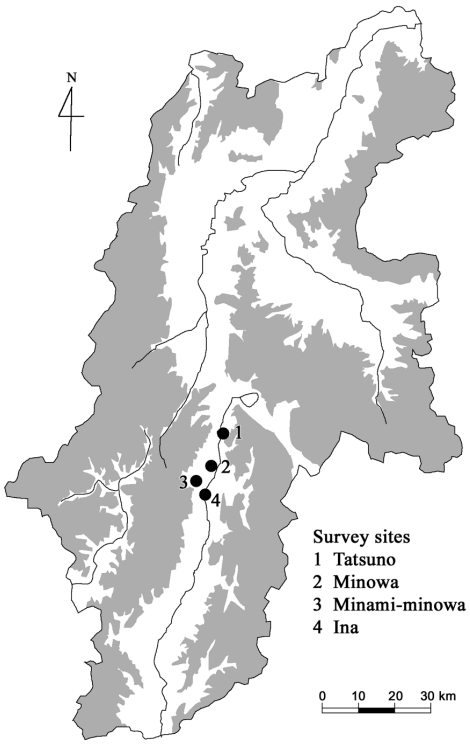

Fig. 1 Location of survey sites in Nagano Prefecture. Shaded area shows mountain zones of over 1,000 m above sea level.

Table 1 Survey sites

No.	Site	Elevation (m)	Environment
1	Tatsuno	700	Levee of a paddy field
2	Minowa	660	Roadside
3	Minami-minowa	755	Roadside
4	Ina	625	Slope of Tenryu Riverbank

In the present study, we assessed the current state of the naturalization of *Tragopogon* species in the Kami-ina region. The identification of naturalized species was determined, and habitat environment and vegetation were investigated.

Methods

Four survey sites with communities of salsify were established in the Kami-ina region; Tatsuno, Minowa, Minami-minowa and Ina (Fig. 1). Tatsuno was the nearest site where we had first observed salsify (*T. porrifolius* with violet flower and *T. dubius* with yellow flower) and collected their specimens in the Kami-ina region in 2007 (Arase, unpublished data). Each site was located at elevations of 600 to 755 m,

on the roadside or cut-slope vegetation (Table 1 and Fig. 2).

Fig. 2 Naturalization of *Tragopogon dubius*. Among roadside vegetation in Minowa Town, in May 2018.

At first, reproductive growth (flower and fruit setting) was checked at each site in May and August 2018, in order to identify the species and to decide whether regeneration would be successful.

Vegetation survey (2 m × 10 m survey plot per site) was conducted in August 2018. As only the herbaceous layer developed at each site, vegetational layers were not divided in the survey. Species name, coverage and sociability were recorded. Plant coverage was ranked using classes from the Braun-Blanquet scale as follows:

+: vegetation was sparse and covered an area less than 1% of the total plot;

1: vegetation covered between 1 and 10% of total plot area;

2: vegetation covered between 10 and 25% of total plot area;

3: vegetation covered between 25 and 50% of total plot area;

4: vegetation covered between 50 and 75% of total plot area;

5: vegetation covered more than 75% of total plot area.

Sociability, the estimate of dispersion of species within the plot, was also ranked using the Braun-Blanquet scale as follows:

1: single individuals;

2: grouped or tufted;

3: in troops or small patches;

Fig. 3 Growth of of *Tragopogon dubius*. Top: flower and fruit setting in May 2018. Bottom: tussock-like radical leaves after reproductive growth in August 2018. White scale in bottom figure = 30 cm.

4: in small colonies or extensive patches;

5: in pure populations forming carpets.

Recorded species in the vegetation survey were categorized into native and naturalized species, by referring to Shimizu (2003), and Tachikake and Nakamura (2007). The ratio of naturalized species was calculated at each site, based on the number of species. Differences of the ratio among sites were analyzed by the binomial test.

Results

Flowering and fruit setting, as well as wintering tussocks, were observed at each site (Fig. 3). Judging from the morphology of flowers, the naturalized salsify in the survey sites was confirmed to be only one species, *Tragopogon dubius*.

Seeds of *T. dubius* are shown in Fig. 4. We harvested the seeds from the Minami-minowa site in August 2018, stored them in a paper bag and dried them at room temperature for three months, and measured the size and weight for 20 seeds. Seed

length and pappus length (radius) were 21.0 ± 1.7 mm and 19.6 ± 1.6 mm, respectively; air-dried seed weight and pappus weight were 5.5 ± 1.3 mg and 1.6 ± 0.4 mg, respectively (mean ± 1 standard deviation).

Fig. 4 Seeds of *Tragopogon dubius*. Harvested in Minami-minowa Village, in August 2018.

Table 2 shows the species composition of the vegetation at the four sites. Most species were herbaceous plants, but the community height differed among the sites; the height was low in Tatsuno and Minowa (0.15 to 0.40 m), high in Minami-minowa and Ina (1.50 m). There were 25 to 45 species per site, and 42% to 68% of the species were naturalized. The ratio of naturalized species was significantly different among the sites (p<0.05, binomial test); the ratio was lowest in Tatsuno (42%), and increased with distance from Tatsuno.

Coverage of *T. dubius* was rank 2 (between 10 and 25%) at most at each site. *Artemisia indica* var. *maximowiczii* (native perennial) and *Oenothera biennis* (naturalized biennial) co-existed with *T. dubius* at each site. In Tatsuno, there were no predominant species, and small clusters were formed by various weeds with stolon (e.g., white clover: *Trifolium repens*), with climbing stem (e.g., *Paederia foetida*), and with elect stem (e.g., *Amaranthus powellii*). In addition to these spontaneous species, lined plants of *Chrysanthemum morifolium* (horticultural flowering plant) were observed at regular intervals. In Minowa, *Setaria faberi* (annual Poaceae weed) dominated about half of the sites, and small clusters were formed by *Glycine max* ssp. *soja* (annual weed with climbing stem) and *Geranium carolinianum* (perennial weed with branching stem). In Minami-minowa, annual to biennial weed (rye brome: *Bromus secalinus*) were predominant. In Ina, perennial Poaceae grasses (tall fescue: *Schedonorus arundinaceus*; Kentucky bluegrass: *Poa pratensis*) and a perennial lespedeza (*Lespedeza cuneata*) were predominant.

Discussion

Naturalized salsify was identified as *T. dubius* at each site in the present study. The regeneration of the *T. dubius* community appeared to be successful because its flowering, fruit setting, and wintering tussocks were observed at each site (Fig. 3). This is the first official record of the naturalization of *T. dubius* in the Kami-ina region. It is possible that the records of naturalized *Tragopogon* species, in other regions in Nagano Prefecture, involved the incorrect identification of *T. dubius* for *T. pratensis*.

It is interesting that only *T. dubius* expanded its habitat, although we had observed other *Tragopogon* species near the Tatsuno site in 2007. The reason for this is unclear, as little information is available to compare the ecological or physiological properties of the naturalized *Tragopogon* species in Japan to date. In our survey site, *T. dubius* seemed to have invaded the open environment of vacant land (roadside) or herbaceous vegetation (bank slope) containing many naturalized non-native species (Table 2). As such habitats have also been mentioned for *T. porrifolius* and *T. pratensis* (Shimizu, 2003), *T. dubius* may have some advantages in seed dispersal, germination, growth, or tolerance to disturbance, as compared with other species.

Judging from the species composition (Table 2), the vegetation in the Tatsuno site seems to have been arranged as a flower-growing garden, and then weeds invaded from the surrounding fields. Vegetation of the Minowa and Minami-minowa sites showed the early stages of succession in vacant roadside areas without planting. Vegetation at the Ina site appears to have been arranged as grassland seeded with pasture grass and legumes to conserve the bank slope, and then many naturalized non-native species invaded by wind or flood from the river basin.

Table 2a Species composition of survey sites (part 1)

Species name	Site			
	Tatuno	Minowa	Minami-minowa	Ina
Community height (m)	0.15	0.40	1.50	1.50
Number of species				
Naturalized	19	20	20	17
Native	26	14	14	8
Total	45	34	34	25
Ratio of naturalized species (%)	42.2 b	58.8 ab	58.8 ab	68.0 a
Artemisia indica var. *maximowiczii*	2・2	+	1・1	2・2
* *Tragopogon dubius*	1・2	1・1	1・2	1・1
* *Oenothera biennis*	+	+	2・3	+
Digitaria ciliaris	2・3	1・2	1・2	
Acalypha australis	1・2	1・2	1・1	
* *Rumex obtusifolius*	1・1	+	1・1	
* *Oxalis dillenii*	+	1・1	1・1	
* *Taraxacum officinale*	1・1	+	1・1	
* *Euphorbia nutans*	+	1・1	+	
Equisetum arvense	1・1	+	+	
* *Conyza canadensis*	+	+	1・1	
* *Euphorbia maculata*	+	+	+	
* *Bidens* sp.	+	+	+	
Calystegia pubescens	+	+	+	
* *Vulpia myuros* var. *myuros*	1・2			1・2
* *Trifolium repens*	1・2	+		
Paederia foetida	1・2		+	
* *Amaranthus powellii*	1・1			
Pterocypsela indica	1・1			
Elymus tsukushiensis var. *transiens*	1・1			
Portulaca oleracea	1・1			
Chrythanthemum morifolium (planted)	1・1			
* *Erigeron philadelphicus*	1・1			
* *Leucanthemum vulgare*	1・1			
Akebia quinata	+			
Stachys aspera var. *hispidula*	+			
Achyranthes bidentata	+			
Stellaria aquatica	+			
Vicia tetrasperma	+			
Cyperus microiria	+			
Geranium thunbergii	+			
* *Agrostis gigantea*	+			
Rorippa palustris	+			
Oenanthe javanica ssp. *javanica*	+			
Scutellaria sp.	+			
Euonymus fortunei var. *fortunei*	+			
Sonchus oleraceus	+			
* *Senecio vulgaris*	+			
Polygonum aviculare ssp. *aviculare*	+			

* denotes naturalized species in Japan.

Different letters in the column of 'ratio of naturalized species (%)' denote significant difference as determined by binomial test ($p < 0.05$).

Table 2b Species composition of survey sites (part 2)

	Species name	Site			
		Tatuno	Minowa	Minami-minowa	Ina
*	*Bromus catharticus*	1・2	2・2		
	Persicaria longiseta	+	+		
*	*Veronica persica*	+	+		
	Commelina communis var. *communis*	+	+		
	Setaria faberi	+	3・3	+	
	Glycine max ssp. *soja* var. *soja*		1・1	+	
*	*Geranium carolinianum*		1・1		
	Setaria viridis		+		
	Humulus scandens		+		
*	*Solidago altissima*		+		
	Metaplexis japonica		+	+	+
*	*Trifolium pratense*		+	+	+
	Chenopodium album var. *album*		+	+	
*	*Lactuca serriola*		+	+	
*	*Vicia villosa* ssp. *varia*		1・1		2・2
*	*Gypsophila muralis*		+		+
*	*Bromus secalinus*			4・4	+
*	*Lepidium virginicum*		+	1・1	
	Vicia cracca			1・2	
*	*Abutilon theophrasti*			+	
*	*Ambrosia trifida*			+	
	Eleusine indica			+	
	Rosa multiflora var. *multiflora*			+	
*	*Carduus crispus*			+	
	Wisteria floribunda			+	
*	*Phytolacca americana*			+	
*	*Erigeron annuus*		+	2・2	1・1
*	*Elymus repens* var. *repens*			1・2	1・2
*	*Verbascum thapsus*			+	+
*	*Schedonorus arundinaceus*	+			4・4
	Zoysia japonica		+		1・5
*	*Poa pratensis* ssp. *pratensis* var. *pratensis*				2・2
	Lespedeza cuneata var. *cuneata*				2・2
*	*Arrhenatherum elatius* var. *elatius*				1・2
*	*Helianthus tuberosus*				1・2
	Pueraria lobata ssp. *lobata*				1・2
*	*Silene armeria*				1・2
	Miscanthus sacchariflorus				1・1
*	*Robinia pseudo-acacia*				1・1
	Phyllanthus lepidocarpus				+
*	*Petrorhagia* sp.				+
	Kummerowia striata				+

* denotes naturalized species in Japan.

The origin of *T. dubius* in newly naturalized sites (Minowa, Minami-minowa and Ina) was unknown in the present survey. However, it is reasonable to consider that salsify invaded by means of seed dispersal; seed of *Tragopogon* species have a large pappus with low Reynolds number, and can be carried by the wind (Matsui and Sudo 2008). The seeds or roots were not thought to have been brought with soil movement by engineering work, as the seeds are short-lived (Qi *et al*. 1996) and emergence of seedlings decreased acutely with increasing seeding depth in *T. dubius* (Qi and Upadhyaya, 1993).

Conclusions

In the present study, we surveyed naturalized salsify at four sites in the Kami-ina region of Nagano Prefecture in 2018. The results were as follows:

1. Naturalized salsify comprised only one species, *Tragopogon dubius*. Flowering, fruit setting, and wintering tussocks of salsify were observed at each site.
2. *T. dubius* seemed to invade the open environment of vacant land (roadside) or herbaceous vegetation (bank slope) containing many naturalized non-native species.
3. The origin of *T. dubius* was unknown in the present survey, but it is likely that it invaded by means of wind-dependent seed dispersal.

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