Semple, J.C. and K. Sankara Rao. 2017. *Solidago altissima* var. *pluricephala* (Asteraceae: Astereae) in India. Phytoneuron 2017-32: 1–6. Published 28 April 2017. ISSN 2153 733X

SOLIDAGO ALTISSIMA VAR. PLURICEPHLA (ASTERACEAE: ASTEREAE) IN INDIA

JOHN C. SEMPLE
Department of Biology, University of Waterloo
Waterloo, Ontario, Canada N2L 3G1
jcsemple@uwaterloo.ca

K. SANKARA RAO
Herbarium, Center for Ecological Sciences,
Indian Institute of Science (IISc)
Bangalore 560012, Karnataka, India

ABSTRACT

Herbarium collections of *Solidago* in Kew Herbarium from southern India are reported here to be *Solidago altissima* var. *pluricephala* M.C. Johnston, which is previously unreported for the country. An additional collection in JCB from Bangalore also is var. *pluricephala*. All specimens have densely hispid-strigose stems (sparsely to densely so proximally and densely so distally and in the inflorescence, lanceolate trinervate upper stem leaves with mostly entire or minutely serrate margins and moderately to densely strigose abaxial surfaces on the main and prominent lateral veins. Specimens of var. *pluricephala* have secund conical inflorescences that are much longer than wide, while those of var. *altissima* tend to be nearly as wide as long.

Solidago altissima L. is native to North American and is a member of *Solidago* subsect. *Triplinerviae* (Torr. & A. Gray) Nesom (Semple & Cook 2006). The species includes plants with densely hispid-strigose stems (sparsely to densely so proximally and densely so distally and in the inflorescence), lanceolate upper stem leaves with mostly entire margins (lower and mid stem leaves are usually serrate), and moderately to densely strigose abaxial surfaces on the main and prominent lateral veins. Three varieties are recognized and differ in distribution, upper leaf shape, size and number of upper stem leaf serrations, and inflorescence shape (Semple et al. 2015). The typical race ssp./var. *altissima* is common to abundant in the northern half of the eastern deciduous forest region of North America. Var. *pluricephala* M.C. Johnston is native to the southeastern USA from Maryland to Florida west to Oklahoma and south Texas. Subspecies/var. *gilvocanescens* (Rydb.) Semple is native to the prairies on the Great Plains from Alberta to Manitoba south to northern Texas; it also occurs in scattered prairie habitats further east. The typical race has been known to be invasive in Eurasia and Oceania for many years though often reported under *S. canadensis* L. or *S. canadensis* var. *scabra* (Muhl. ex Willd.) Torr. & Gray (China, Japan) or *S. altissima* (Chen & Semple 2011). Sakata et al. (2015) described how a few introductions could result in large scale invasion of *S. altissima* in Japan. Cheek and Semple (2016) documented the occurrence of var. pluricephala in South Africa. Verloove et al. (2017) recently documented the occurrence of var. *altissima* in Belgium.

Only hexaploids of *Solidago altissima* have been reported from South Asia (Sarkar et al. 1980; Bala and Gupta 2013, as *S. canadensis*), Japan (Huziwara, Y. 1962; Sakata et al. 2013a, b), and Taiwan (Peng & Hsu 1978). In North America, diploids and tetraploids occur in *S. altissima* var. *gilvocanescens* with a few tetraploids and predominantly hexaploids being reported for var. *altissima* and var. *pluricephala* (Semple et al. 2015).

During a visit to Kew Herbarium (K) in late 2014, a number of Eurasian and Oceanian collections of what appeared to be either *Solidago chilensis* or *S. altissima* were examined among the general collections of *Solidago*. These were borrowed from K for more detailed examination and scoring for comparison with specimens of the four species of *Solidago* known to be adventive in

countries outside North and South America (*S. altissima*, *S. canadensis*, *S. chilensis*, *S. gigantea*) and some of which were included in multivariate analyses (Semple et al. 2015; Lopez Laphitz & Semple 2015). Some *S. altissima* var. *pluricephala* plants from India have previously been misidentified as *S. canadensis* or *S. microglossa* DC.

Specimens of *Solidago altissima* var. *pluricephala* examined. **INDIA.** Karnataka Prad. Bangalore, *Sankara Rao s.n.* (JCB HJCB028). Tamil Nadu Prad. Kodaikanal Dist., Palni (Pluney) Hills, Dindigul, Herb, 2 m; in garden planted along hedges, 2100 m, 7 Sep 1988, *Matthew s.n.* (K); Yercad Dist., Salem, Servarayans, loop road 2 km to Cuvery Peak, herb., escape from garden, 21 Mar 1979, *Venugopal & Jayaseelan s.n.* (K; Figs. 1 and 2).

The *Venugopal & Jayaseelan s.n.* (K) collection was included in a multivariate analysis of 291 specimens of *Solidago altissima*, *S. canadensis S. chilensis*, and *S. gigantea* following the methods described in Semple et al. (2015). The STEPWISE discriminant analysis selected 10 traits listed in decreasing order of F-to-remove values: outer phyllary length (25.65), length of disc floret corolla at anthesis (23.95), number of disc florets (11.05), upper stem leaf width (12.93), upper stem leaf length (11.38), number of mid stem leaf margin serrations (9.15), disc floret pappus length at anthesis (9.08), number of upper stem leaf margin serrations (8.98), disc corolla lobe length (8.80), disc floret achene body length at anthesis (8.49), and involucre height at anthesis (6.70). Wilks's lambda, Pillai's trace, and Lawley-Hotelling trace tests of the null hypothesis that all groups were the samples of one group had probabilities of p = 0.000 that the null hypothesis was true. The F-matrix for the discriminant analysis is presented in Table 1. F-values based on Mahalanobis distances of the between group centroids indicated the largest separations were between *S. canadensis* and *S. chilensis* (81.691), and *S. altissima* and *S. chilensis* (71.206); the smallest separation was between *S. altissima* and *S. candensis* (29.843).

Table 1. Between groups F-matrix for the four a priori group analysis (df = 11 277).

Group	*altissima*	*canadensis*	*chilensis*
canadensis	29.843		
chilensis	71.206	81.691	
gigantea	41.147	31.344	57.754

Wilks' lambda = 0.0409 df = 119 3 287; Approx. F= 48.4692 df = 33 816 prob = 0.0000

In the Classificatory Discriminant Analysis of the *Solidago altissima*, *S. canadensis S. chilensis*, and *S. gigantea* species level a priori groups, a posteriori assignments of specimens ranged from 86-98% to their own group. The Classification matrix and Jackknife classification matrix are presented in Table 2. *Venugopal & Jayaseelan s.n.* (K; yellow stars in Fig. 3) was included in the *S. altissima* a priori group and was assigned a posteriori to the *S. altissima* group with 89% probability (11% to *S. chilensis*).

Two dimensional plots of CAN1 versus CAN3 and CAN1 versus CAN2 canonical scores for 69 specimens of *Solidago jejunifolia*, *S. pallida*, *S. rigidiuscula*, and *S. speciosa* are presented in Figure 12. Eigenvalues on the first three axes are 3.259, 1.099 and 0.774.

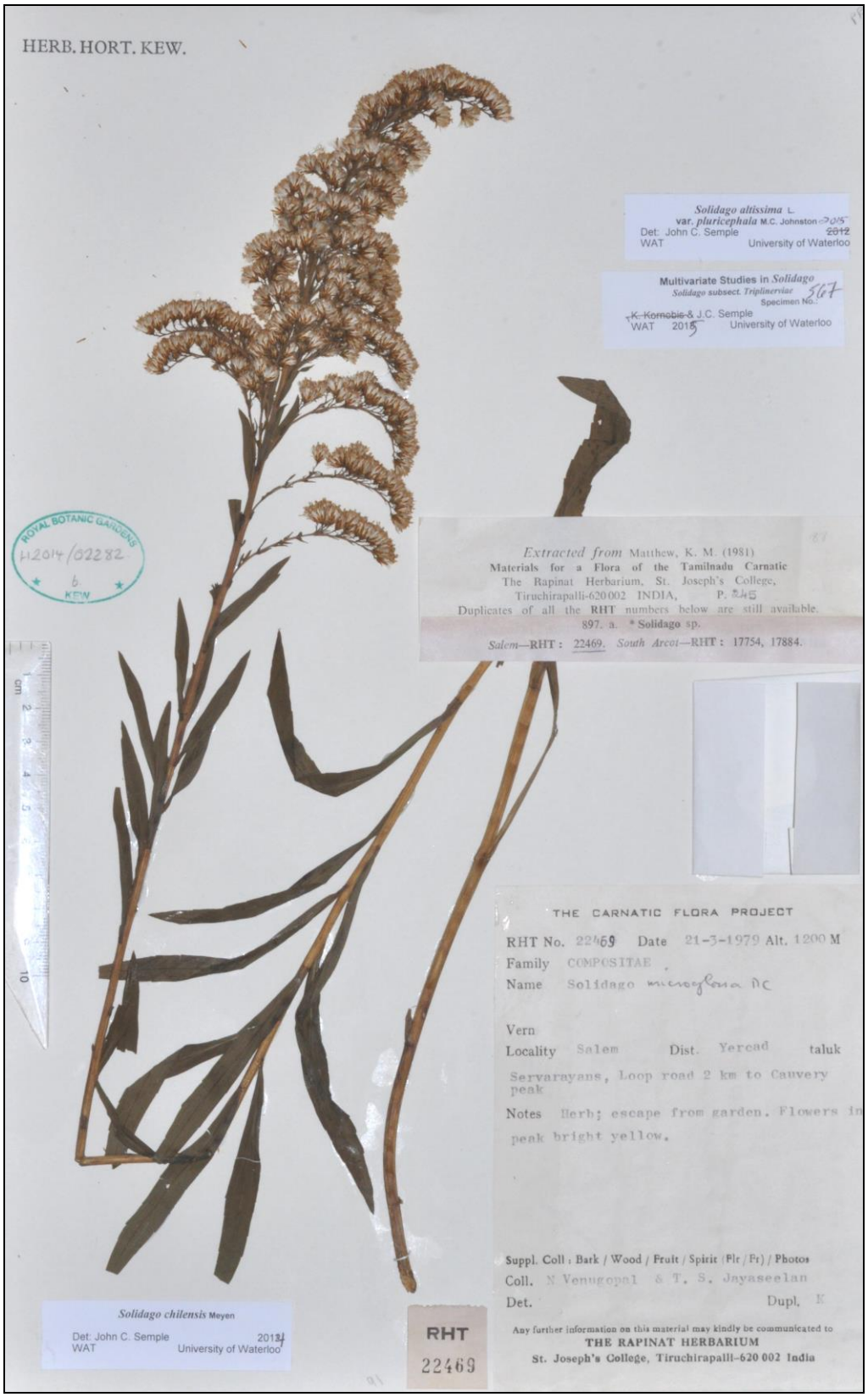

Figure 1. *Solidago altissima* var. *pluricephala* from India: *Venugopal & Jayaseelan 22469* (K).

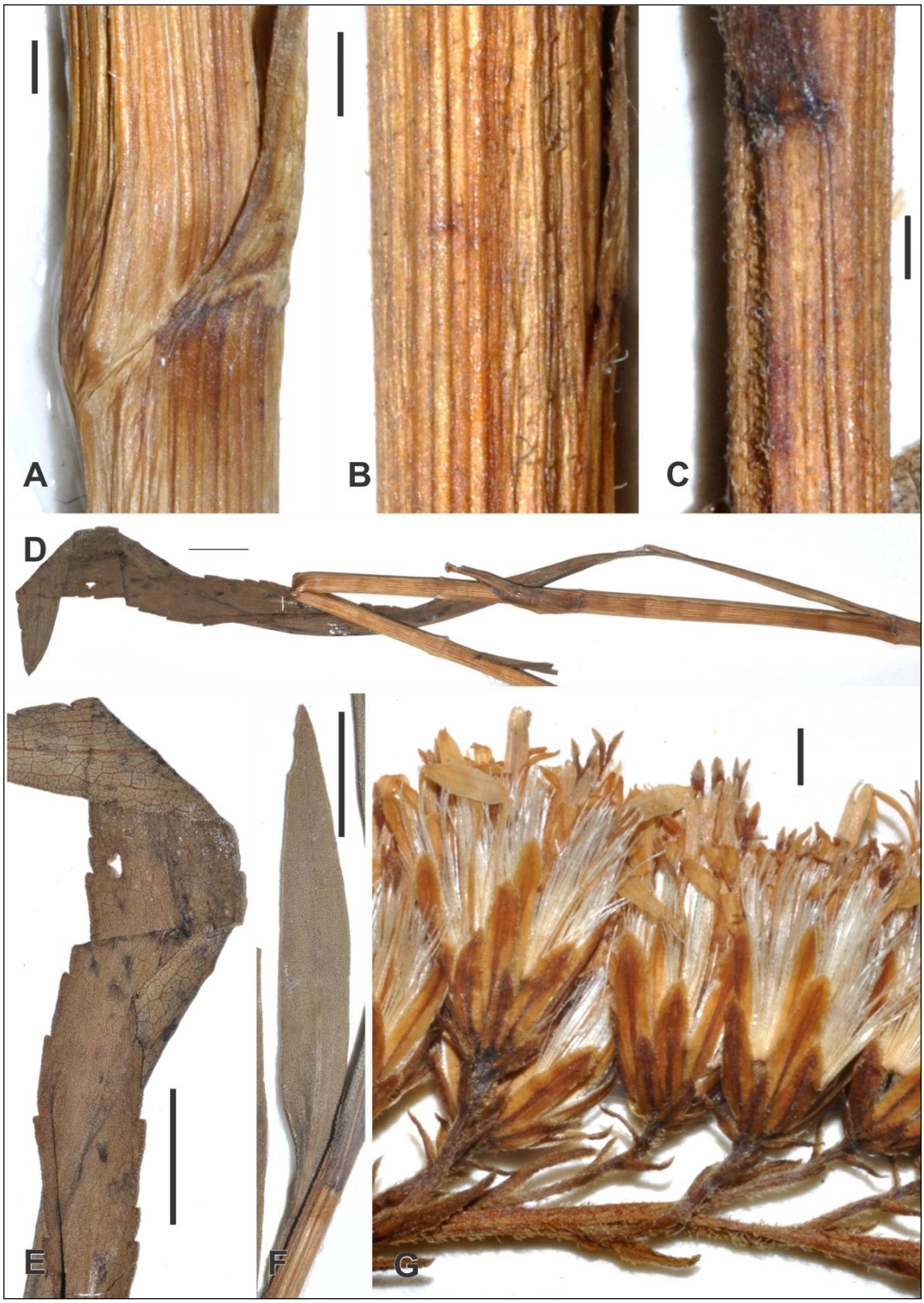

Figure 2. Details of *Solidago altissima* var. *pluricephala* from India: *Venugopal & Jayaseelan 22469* (K). **A.** Lower stem. **B.** Mid stem. **C.** Upper stem. **D-E.** Lower stem leaf. **F.** Upper stem leaf. **G.** Heads on lower inflorescence branch. Scale bar = 1 mm in A-C, G; 1 cm in D-F.

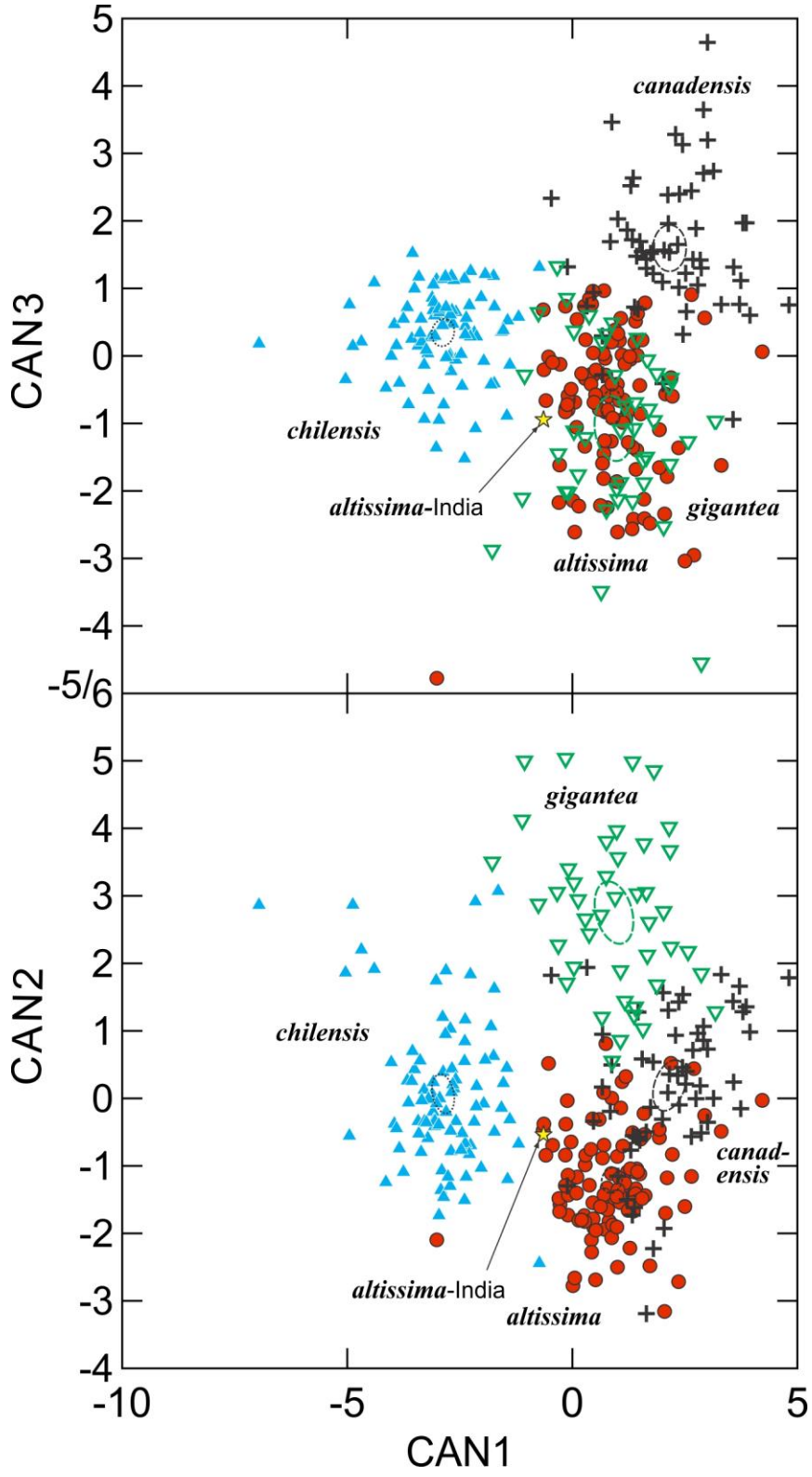

Figure 3. Plot of canonical scores (CAN1 vs CAN3 and CAN1 vs CAN2) for 291 specimens of adventive species of *Solidago*: *S. altissima* from India (yellow stars), *S. altissima* (red dots), *S. canadensis* (black +s), *S. chilensis* (blue triangles), and *S. gigantea* (green inverted open triangles).

Table 2. Linear and jackknife classification matrices from the Classificatory Discriminant Analysis of four a priori groups; a posteriori placements to groups in rows.

Group	*altissima*	*canadensis*	*chilensis*	*gigantea*	% correct
altissima	100	5	1	0	94
canadensis	4	49	0	4	86
chilensis	1	0	86	1	98
gigantea	0	1	0	39	98
Totals	105	55	87	44	94

Jackknifed classification matrix

Group	*altissima*	*canadensis*	*chilensis*	*gigantea*	% correct
altissima	96	6	2	2	91
canadensis	5	48	0	4	84
chilensis	1	1	85	1	97
gigantea	2	3	1	34	85
Totals	104	58	88	41	90

ACKNOWLEDGEMENTS

This work was supported by a Natural Sciences and Engineering Research Council of Canada Discovery Grants to the first author. Joan Venn is thanked for her curatorial assistance with loans. Kew Herbarium is thanked for assistance during my visit in November 2014 and for the loan of specimens of *Solidago*; Nicholas Hind is thanked for his help and discussions on multiple matters Compositae while at Kew. The following herbaria are thanked for loaning specimens of *Solidago* subsect. *Triplinerviae* and giving permission to dissect heads: BM, GH, K, LL, MADS, MEL, MO, the John K. Morton personal herbarium now deposited in TRT, MIN, PERTH, TEX, and WAT in MT Andrew Lam assisted in recording location data on specimens of *Solidago* subsect. *Triplinerviae*. The following students assisted in collecting morphological data: Sofia Bzovsky, Y. Alex Chong, Haris Faheemuddin, Imran Khamis, Katherine Kornobis, Rita Lopez Laphitz, Hammad Rahman, and Mariam Sorour.

LITERATURE CITED

Bala, S. & Gupta, R.C. 2013. Male meiosis and chromosome number in Asteraceae family from district Kangra of H. P. (Western Himalayas). Internatl. J. Bot. Res. 3: 43–58.

Cheek, M. D. and J.C. Semple. 2016. First official record of naturalised populations of *Solidago altissima* L. var. *pluricephala* M.C. Johnst. (Asteraceae: Astereae) in Africa. South Afr. J. Bot. 105: 333-336.

Chen, Y., and J.C. Semple. 2011. *Solidago* Linnaeus. Pp. 632–634, in Z.Y. Wu, P.H. Raven, & D.Y. Hong (eds.). Flora of China, Volume 20–21 (Asteraceae). Science Press (Beijing) & Missouri Botanical Garden Press (St. Louis).

Huziwara, Y. 1962a. Karyotype analysis in some genera of Compositae. VII. The chromosomes of Japanese *Solidago* species. Acta Phytotax. Geobot. 20: 176–178.

Iwatsuki, K., T. Yamazaki, D.E. Boufford, and H. Ohba (eds.). 1995. Flora of Japan, Vol. IIIb: Angiospermae, Dicotyledoneae, Sympetalae (b). Kodansha, Ltd., Tokyo.

Lopez Laphitz, R. and J.C. Semple. 2015. A multivariate morphometric analysis of the *Solidago chilensis* complex in South America and related taxa in North America (Asteraceae: Astereae). Ann. Missouri. Bot. Garden 100: 423–441.

Peng, C.I. and C.C. Hsu. 1977. In IOPB chromosome number reports LVIII. Taxon 26: 557–565.

Sakata Y, Ohgushi T, Isagi Y. 2013a. Geographic variations in phenotypic traits of the exotic herb *Solidago altissima* and abundance of recent established exotic herbivorous insects. J. Pl. Interact. 8: 216–218.

Sakata, Y., S. Kan Seko, A. Hayano, M. Inoue-Murayama, Ohgushi T, Y. Isagi. 2013b. Isolation and characterization of microsatellite loci in the invasive herb *Solidago altissima* (Asteraceae). Appl. Plant Sci.: 1200313.

Sakata, Y., J. Itami, Y. Isagi and T. Ohgushi. 2015. Multiple and mass introductions from limited origins: Genetic diversity and structure of *Solidago altissima* in the native and invaded range. J. Pl. Res. 128: 909–21.

Sarkar, A.K, M. Chakraveerty, S.K. Das, C.R. Pal, and D. Hazara. 1980. In Chromosome number reports LXVII. Taxon 29: 358–360.

Semple, J.C., H. Rahman, S. Bzovsky, M.K. Sorour, K. Kornobis, R. Lopez Laphitz, and L. Tong. 2015. A multivariate morphometric study of the *Solidago altissima* complex and *S. canadensis* (Asteraceae: Astereae). Phytoneuron 2015-10: 1–31.

Verloove F., B.J.M. Zonneveld and J.C. Semple. 2017: First evidence for the presence of invasive *Solidago altissima* (*Asteraceae*) in Europe. Willdenowia 47: 69-75.