

Supplementary Information 1

Life history of the harlequin ladybird, *Harmonia axyridis*; a global meta-analysis

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Reference list of selected studies that provided data for the meta-analysis. Raw data of selected studies are deposited at <http://dx.doi.org/10.17026/dans-zt7-dhb6>.

Agarwala BK, Bhowmik PJ (2011) Effect of resource gradient on age and size at maturity and their influence on early-life fecundity in the predatory Asian lady beetle, *Harmonia axyridis*. Entomol Exp Appl 141:97-102

Agarwala BK, Yasuda H, Sato S (2008) Life history response of a predatory ladybird, *Harmonia axyridis* (Pallas) (Coleoptera: Coccinellidae), to food stress. Appl Entomol Zool 43:183-189

Ali I, Zhang S, Luo J-Y, Wang C-Y, Lv L-M, Cui J-J (2016) Artificial diet development and its effect on the reproductive performances of *Propylea japonica* and *Harmonia axyridis*. J Asia-Pacif Entomol 19:289-293

Benelli M, Leather SR, Francati S, Marchetti E, Dindo ML (2015) Effect of two temperatures on biological traits and susceptibility to a pyrethroid insecticide in an exotic and native coccinellid species. B Insectol 68:23-29

Berkvens N, Bonte J, Berkvens D, Deforce K, Tirry L, De Clercq P (2008a) Pollen as an alternative food for *Harmonia axyridis*. BioControl 53:201-210

Berkvens N, Bonte J, Berkvens D, Tirry L, De Clercq P (2008b) Influence of diet and photoperiod on development and reproduction of European populations of *Harmonia axyridis* (Pallas) (Coleoptera: Coccinellidae). BioControl 53:211-221

Butin EE, Havill NP, Elkinton JS, Montgomery ME (2004) Feeding preference of three lady beetle predators of the hemlock woolly adelgid (Homoptera: Adelgidae). J Econ Entomol 97:1635-1641

Chen J, Qin QJ, Liu S, He YZ (2012) Effect of six diets on development and fecundity of *Harmonia axyridis* (Pallas) (Coleoptera: Coccinellidae). Afr Entomol 20:85-90

Cottrell T-E (2004) Suitability of exotic and native lady beetle eggs (Coleoptera: Coccinellidae) for development of lady beetle larvae. Biol Control 31:362-371

- Dixon AFG, Agarwala BK (2002) Triangular fecundity function and ageing in ladybird beetles. *Ecol Entomol* 27:433-440
- Dmitriew C, Rowe L (2007) Effects of early resource limitation and compensatory growth on lifetime fitness in the ladybird beetle (*Harmonia axyridis*). *J Evol Biol* 20:1298-1310
- Evans EW, Gunther DI (2005) The link between food and reproduction in aphidophagous predators: a case study with *Harmonia axyridis* (Coleoptera: Coccinellidae). *Eur J Entomol* 102:423-430
- Ferran A, Giuge L, Tourniaire R, Gambier J, Fournier D (1998) An artificial non-flying mutation to improve the efficiency of the ladybird *Harmonia axyridis* in biological control of aphids. *BioControl* 43:53-64
- Grill CP, Moore AJ (1998) Effects of a larval antipredator response and larval diet on adult phenotype in an aposematic ladybird beetle. *Oecologia* 114:274-282
- Grill CP, Moore AJ, Brodie ED, III (1997) The genetics of phenotypic plasticity in a colonizing population of the ladybird beetle, *Harmonia axyridis*. *Heredity* 78:261-269
- Guo J, Wan F (2001) Effect of three diets on development and fecundity of the ladybeetles *Harmonia axyridis* and *Propylaea japonica*. *Chinese Journal of Biological Control* 17:116-120
- He JL, Ma EP, Shen YC, Chen WL, Sun XQ (1994) Observations of the biological characteristics of *Harmonia axyridis* (Pallas) (Coleoptera: Coccinellidae). *Journal of Shanghai Agricultural College* 12:119-124
- Hukusima S, Kamei M (1970) Effects of various species of aphids as food on development, fecundity and longevity of *Harmonia axyridis* Pallas (Coleoptera: Coccinellidae). *Res bull fac agric Gifu Univ* 29:53-66
- Hukusima S, Ohwaki T (1972) Further notes on feeding biology of *Harmonia axyridis* Pallas (Coleoptera: Coccinellidae). *Res bull fac agric Gifu Univ* 33:75-82
- Jing Y, Yong-Jie Z, Ma R-y (2002) Studies on the bionomics of *Harmonia axyridis* (Pallas) in Shanxi Province. *J. Shanxi Agric Univ.* 22:42-45
- Kalaskar A, Evans EW (2001) Larval responses of aphidophagous lady beetles (Coleoptera: Coccinellidae) to weevil larvae versus aphids as prey. *Ann Entomol Soc Am* 94:76-81
- Kawauchi S (1979) Effects of temperatures on the aphidophagous coccinellids. *Kurume Univ J* 28:47-51
- Kim GH, Choi SY (1985) Effects of the composition of artificial diets on the growth and ovarian development of an aphidivorous coccinellid beetle (*Harmonia axyridis* Pallas: Coccinellidae, Coleoptera). *Korean J Entomol* 15:33-41
- Knapp M (2014) Emergence of sexual size dimorphism and stage-specific effects of elevated temperature on growth rate and development rate in *Harmonia axyridis*. *Physiol Entomol* 39:341-347

- Knapp M, Nedved O (2013) Gender and timing during ontogeny matter: effects of a temporary high temperature on survival, body size and colouration in *Harmonia axyridis*. PLoS One 8(9):e74984
- Kögel S, Eben A, Hoffmann C, Gross J (2012) Influence of diet on fecundity, immune defense and content of 2-isopropyl-3-methoxypyrazine in *Harmonia axyridis* Pallas. J Chem Ecol 38:854-864
- Kögel S, Schieler M, Hoffmann C (2013) The ladybird beetle *Harmonia axyridis* (Coleoptera: Coccinellidae) as a possible predator of grape phylloxera *Daktulosphaira vitifoliae* (Hemiptera: Phylloxeridae). Eur J Entomol 110:123-128
- Kraiss H, Cullen EM (2008a) Efficacy and nontarget effects of reduced-risk insecticides on *Aphis glycines* (Hemiptera : Aphididae) and its biological control agent *Harmonia axyridis* (Coleoptera : Coccinellidae). J Econ Entomol 101:391-398
- Kraiss H, Cullen EM (2008b) Insect growth regulator effects of azadirachtin and neem oil on survivorship, development and fecundity of *Aphis glycines* (Homoptera : Aphididae) and its predator, *Harmonia axyridis* (Coleoptera : Coccinellidae). Pest Manag Sci 64:660-668
- Krengel S, Stangl GI, Brandsch C, Freier B, Klose T, Moll E, Kiowski A (2012) A comparative study on effects of normal versus elevated temperatures during preimaginal and young adult period on body weight and fat body content of mature *Coccinella septempunctata* and *Harmonia axyridis* (Coleoptera: Coccinellidae). Environ Entomol 41:676-687
- Kuang R-P, Xiao N-N (1995) Growth patterns of the ladybird (*Harmonia axyridis* Pallas) relative to variations in population genetics. Insect Sci Appl 16:35-38
- Labrie G, Lucas E, Coderre D (2006) Can developmental and behavioral characteristics of the multicolored Asian lady beetle *Harmonia axyridis* explain its invasive success? Biol Invasions 8:743-754
- LaMana ML, Miller JC (1998) Temperature-dependent development in an Oregon population of *Harmonia axyridis* (Coleoptera: Coccinellidae). Environ Entomol 27:1001-1005
- Lanzoni A, Accinelli G, Bazzocchi GG, Burgio G (2004) Biological traits and life table of the exotic *Harmonia axyridis* compared with *Hippodamia variegata*, and *Adalia bipunctata* (Col., Coccinellidae). J Appl Entomol 128:298-306
- Lombaert E, Malausa T, Devred R, Estoup A (2008) Phenotypic variation in invasive and biocontrol populations of the harlequin ladybird, *Harmonia axyridis*. BioControl 53:89-102
- Lundgren JG, Hesler LS, Tilmon K, Dashiell K, Scott R (2009) Direct effects of soybean varietal selection and *Aphis glycines*-resistant soybeans on natural enemies. Arthropod-Plant Interact 3:9-16
- McClure MS (1987) Potential of the Asian predator, *Harmonia axyridis* Pallas (Coleoptera: Coccinellidae), to control *Matsucoccus resinosae* Bean and Godwin (Homoptera: Margarodidae) in the United States. Environ Entomol 16:224-230

- Michaud JP, Grant AK (2003) Sub-lethal effects of a copper sulfate fungicide on development and reproduction in three coccinellid species. *J Insect Sci* 3:6
- Mignault MP, Roy M, Brodeur J (2006) Soybean aphid predators in Quebec and the suitability of *Aphis glycines* as prey for three Coccinellidae. *BioControl* 51:89-106
- Moser SE, Obrycki JJ (2009) Competition and intraguild predation among three species of coccinellids (Coleoptera: Coccinellidae). *Ann Entomol Soc Am* 102:419-425
- Nakamura K, Miura K, Jong PWd, Ueno H (2006) Comparison of the incidence of sibling cannibalism between male-killing *Spiroplasma* infected and uninfected clutches of a predatory ladybird beetle, *Harmonia axyridis* (Coleoptera: Coccinellidae). *Eur J Entomol* 103:323-326
- Nedved O, Kalushkov PK (2012) Effect of air humidity on sex ratio and development of ladybird *Harmonia axyridis* (Coleoptera: Coccinellidae). *Psyche* 2012:5
- Obata S (1987) Mating behavior and sperm transfer in the ladybird beetle, *Harmonia axyridis* Pallas (Coleoptera: Coccinellidae). *Appl Entomol Zool* 22:434-442
- Okamoto H (1978) Laboratory studies on food ecology of aphidophagous lady beetles (Coleoptera: Coccinellidae). *Mem Fac Agr Kawaga Univ* 32:1-94
- Ongagna P, Giuge L, Ipert G, Ferran A (1993) Life cycle of *Harmonia axyridis* (Col. Coccinellidae) in its area of introduction: south-eastern France. *Entomophaga* 38:125-128
- Ongagna P, Ipert G (1994) Influence of temperature and photoperiod in *Harmonia axyridis* Pall. (Col., Coccinellidae): rapidly obtaining fecund adults or in dormancy. *J Appl Entomol* 117:314-317
- Osawa N (2002) Sex-dependent effects of sibling cannibalism on life history traits of the ladybird beetle *Harmonia axyridis* (Coleoptera: Coccinellidae). *Biol J Linn Soc* 76:349-360
- Osawa N (2003) The influence of female oviposition strategy on sibling cannibalism in the ladybird beetle *Harmonia axyridis* (Coleoptera: Coccinellidae). *Eur J Entomol* 100:43-48
- Osawa N, Ohashi K (2008) Sympatric coexistence of sibling species *Harmonia yedoensis* and *H. axyridis* (Coleoptera : Coccinellidae) and the roles of maternal investment through egg and sibling cannibalism. *Eur J Entomol* 105:445-454
- Phoofolo MW, Obrycki JJ (1998) Potential for intraguild predation and competition among predatory Coccinellidae and Chrysopidae. *Entomol Exp Appl* 89:47-55
- Qin Q, Liu S, Li S, Zhang W, He Y (2016) Role of photoperiod in the development and reproduction of *Harmonia axyridis* (Coleoptera, Coccinellidae). *Biocontrol Sci Technol* 26:116-124
- Reznik SY, Vaghina NP (2011) Photoperiodic control of development and reproduction in *Harmonia axyridis* (Coleoptera: Coccinellidae). *Eur J Entomol* 108:385-390
- Reznik SY, Vaghina NP (2013) Effects of photoperiod and diet on diapause tendency, maturation and fecundity in *Harmonia axyridis* (Coleoptera: Coccinellidae). *J Appl Entomol* 137:452-461
- Sayed SM, El-Arnaouty SA (2013) Pollen grains as an additional food for Asian lady beetle, *Harmonia axyridis* Pallas (Coleoptera: Coccinellidae). *Life Science Journal* 10:1755-1759

- Schanderl H, Ferran A, Garcia V (1988) Rearing two coccinellids *Harmonia axyridis* and *Semiadalia undecimnotata* on eggs of *Anagasta kuehniella* killed with ultraviolet radiation. *Entomol Exp Appl* 49:235-244
- Schanderl H, Ferran A, Larroque MM (1985) The trophic and thermal requirements of larvae of the coccinellid *Harmonia axyridis* Pallas. *Agronomie* 5:417-421
- Schanderl H, Garcia V, Soares AO (1995) A duração de desenvolvimento larvar, mortalidade e capacidade predadora de algumas espécies de coccinelídeos afidípagos. *Açoreana* 8:95-101
- Seko T, Miura K (2009) Effects of artificial selection for reduced flight ability on survival rate and fecundity of *Harmonia axyridis* (Pallas) (Coleoptera: Coccinellidae). *Appl Entomol Zool* 44:587-594
- Seko T, Miyatake T, Miura K (2012) Assessment of hybrid vigor between flightless lines to restore survival and reproductive characteristics in the ladybird beetle *Harmonia axyridis*. *BioControl* 57:85-93
- Seo MJ, Kim GH, Youn YN (2008) Differences in biological and behavioural characteristics of *Harmonia axyridis* (Coleoptera: Coccinellidae) according to colour patterns of elytra. *J Appl Entomol* 132:239-247
- Soares AO, Coderre D, Schanderl H (2001) Fitness of two phenotypes of *Harmonia axyridis* (Coleoptera: Coccinellidae). *Eur J Entomol* 98:287-293
- Soares AO, Coderre D, Schanderl H (2004) Dietary self-selection behaviour by the adults of the aphidophagous ladybeetle *Harmonia axyridis* (Coleoptera: Coccinellidae). *J Anim Ecol* 73:478-486
- Stathas GJ, Eliopoulos PA, Kontodimas DC, Giannopapas J (2001) Parameters of reproductive activity in females of *Harmonia axyridis* (Coleoptera: Coccinellidae). *Eur J Entomol* 98:547-549
- Stathas GJ, Kontodimas DC, Karamaouna F, Kampouris S (2011) Thermal requirements and effect of temperature and prey on the development of the predator *Harmonia axyridis*. *Environ Entomol* 40:1541-1545
- Stuart RJ, Michaud JP, Olsen L, McCoy CW (2002) Lady beetles as potential predators of the root weevil *Diaprepes abbreviatus* (Coleoptera: Curculionidae) in Florida citrus. *Fla Entomol* 85:409-416
- Sun X, Chen W, Chen Z, He J, Ye W (1996) A preliminary study on the artificial diet of an aphidophagous coccinellid, *Harmonia axyridis* (Pallas) and its use to control strawberry aphids under plastic covering. *Journal of Shanghai Agricultural College* 14:133-137
- Takahashi K (1986) An experiment on the collecting method of eggs of the lady beetles, *Coccinella septempunctata brucki* Mulsant and *Harmonia axyridis* (Pallas) (Coleoptera: Coccinellidae). *Japanese Journal of Applied Entomology and Zoology* 30:62-64

- Tan CC (1933) Notes on the biology of the ladybird beetle, *Ptychanatis axyridis* Pall. Peking Natural History Bulletin 8:9-18
- Tayeh A, Hufbauer RA, Estoup A, Ravigne V, Frachon L, Facon B (2015) Biological invasion and biological control select for different life histories. Nat Commun 6
- Tourniaire R, Ferran A, Giuge L, Gambier J, Brun J (1999) Flightless strains of *Harmonia axyridis* Pallas (Coleoptera: Coccinellidae): some behavioural and biological features. Annales de la Societe Entomologique de France 35:509-513
- Tsaganou FC, Hodgson CJ, Athanassiou CG, Kavallieratos NG, Tomanovic Z (2004) Effect of *Aphis gossypii* Glover, *Brevicoryne brassicae* (L.), and *Megoura viciae* Buckton (Hemiptera: Aphidoidea) on the development of the predator *Harmonia axyridis* (Pallas) (Coleoptera: Coccinellidae). Biol Control 31:138-144
- Turgeon J, Tayeh A, Facon B, Lombaert E, Clercq Pd, Berkvens N, Lundgren JG, Estoup A (2011) Experimental evidence for the phenotypic impact of admixture between wild and biocontrol Asian ladybird (*Harmonia axyridis*) involved in the European invasion. J Evol Biol 24:1044-1052
- Ueno H (2003) Genetic variation in larval period and pupal mass in an aphidophagous ladybird beetle (*Harmonia axyridis*) reared in different environments. Entomol Exp Appl 106:211-218
- Ungerova D, Kalushkov P, Nedved O (2010) Suitability of diverse prey species for development of *Harmonia axyridis* and the effect of container size. IOBC/wprs Bulletin 58:165-174
- Wang H, Ji S, Zhai W (2009) Effect of temperature on survival, development and fecundity of *Harmonia axyridis*. Chin Bull Entomol 46:449-452
- Ware R, Yguel B, Majerus M (2009) Effects of competition, cannibalism and intra-guild predation on larval development of the European coccinellid *Adalia bipunctata* and the invasive species *Harmonia axyridis*. Ecol Entomol 34:12-19
- Yasuda H, Ohnuma N (1999) Effect of cannibalism and predation on the larval performance of two ladybird beetles. Entomol Exp Appl 93:63-67
- Yuan rC, Zhang FM, Wen GZ (1994) Study on control of soybean aphid by *Harmonia (Leis) axyridis*. Ji Lin Agric Sci 44:30-32
- Zhang SZ, Cao Z, Wang QL, Zhang F, Liu TX (2014) Exposing eggs to high temperatures affects the development, survival and reproduction of *Harmonia axyridis*. J Therm Biol 39:40-44
- Zhang X, Chen M, Zhang B, Luo Y, Hou Y, Su X (2009) Survival and development of immature *Harmonia axyridis* (Pallas) feeding on *Chaitophorus populeti* (Panzer) propagated on transgenic *Populus alba* x *P. glandulosa*. Forestry Studies in China 11:164-167
- Zhao J, Chen Z, Zheng F, Zhang F, Yin X, Xu Y (2012) Effects of cold acclimation on developmental characteristics and fitness of *Harmonia axyridis* (Coleoptera: Coccinellidae) offsprings. Acta Entomol Sin 55:810-815

