Next: Spodoptera frugiperda multiple nucleopolyhedrovirus >>
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Datasheet

Spodoptera frugiperda (fall armyworm)

Rwomushana I, 2020. *Spodoptera frugiperda* (fall armyworm). Crop Protection Compendium. Wallingford, UK: CABI. DOI:10.1079/CPC.29810.20210102715

Index

Summary

Last modified
19 October 2021

Datasheet Type(s)
Pest
Natural Enemy

Preferred Scientific Name
Spodoptera frugiperda

Preferred Common Name
fall armyworm

Taxonomic Tree
Domain: Eukaryota
Kingdom: Metazoa
Phylum: Arthropoda

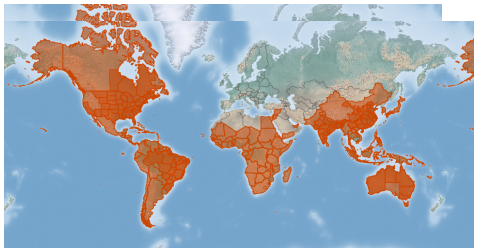
More information

Subphylum: Uniramia
Class: Insecta

Host Plants and Other Plants Affected

Abelmoschus esculentus (okra)
Acalypha (Copperleaf)
Agrostis (bentgrasses)
Agrostis gigantea (black bent)
Agrostis stolonifera (creeping bentgrass)

More...



More information

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Pictures

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Picture	Title	Caption	Copyright
	Museum specimen - adult	Spodoptera frugiperda (fall armyworm); adult. Museum set specimen. LinkS to Spodoptera ID paper: http://www.invasive.org/publications/aphis/Handout_Spodoptera_Wings_2013.pdf - http://www.invasive.org/publications/aphis/Handout_Spodoptera_genitalia.pdf	©Lyle J. Buss/University of Florida/Bugwood.org - CC BY 3.0 US
	Adult Spodoptera frugiperda (fall armyworm)	Spodoptera frugiperda (fall armyworm); adult male. Taken at light, Curepe, Trinidad, West Indies. 28 August 1978. Museum set specimen.	©CABI/Matthew Cock
	Adult Spodoptera frugiperda (fall armyworm)	Spodoptera frugiperda (fall armyworm); adult female. Taken at light, Curepe, Trinidad, West Indies. 06 September 1978. Museum set specimen.	©CABI/Matthew Cock
	Egg mass	Spodoptera frugiperda (fall armyworm); egg mass on cotton (Gossypium hirsutum).	©Ronald Smith/Auburn University/Bugwood.org - CC BY 3.0 US
	Larva	Spodoptera frugiperda (fall armyworm); larva on bermuda grass (Cynodon dactylon).	©Clemson University/USDA Cooperative Extension Slide Series/Bugwood.org - CC BY 3.0 US
	Larval damage	Spodoptera frugiperda (fall armyworm); larval damage in whorl of maize (Zea mays).	©University of Georgia/Bugwood.org - CC BY 3.0 US
	Larval damage	Spodoptera frugiperda (fall armyworm); larval damage on maize (Zea mays).	©University of Georgia/Bugwood.org - CC BY 3.0 US
	Larva	Spodoptera frugiperda (fall armyworm); larva on tomato (Lycopersicon esculentum).	©Alton N. Sparks, Jr./University of Georgia/Bugwood.org - CC BY 3.0 US

Picture	Title	Caption	Copyright
	Larva	Spodoptera frugiperda (fall armyworm); larvae on hay grass. USA. August 2006.	©Chazz Hesselein/Alabama Cooperative Extension System/Bugwood.org - CC BY 3.0 US
	Larva	Spodoptera frugiperda (fall armyworm); larva, on cotton (Gossypium hirsutum). USA.	©Russ Ottens/University of Georgia/Bugwood.org - CC BY 3.0 US
	Larva	Spodoptera frugiperda (fall armyworm); larva, on cotton (Gossypium hirsutum L.). USA.	©Russ Ottens/University of Georgia/Bugwood.org - CC BY 3.0 US
	Larvae	Spodoptera frugiperda (fall armyworm); early instar larvae (arrowed), and damage on cotton boll bract (Gossypium hirsutum).	©Ronald Smith/Auburn University/Bugwood.org - CC BY 3.0 US
	Larval damage	Spodoptera frugiperda (fall armyworm); severe larval damage on cotton boll (Gossypium hirsutum).	©Ronald Smith/Auburn University/Bugwood.org - CC BY 3.0 US
	Larval damage	Spodoptera frugiperda (fall armyworm); larval damage on sorghum (Sorghum bicolor).	©Clemson University/USDA Cooperative Extension Slide Series/Bugwood.org - CC BY 3.0 US
	Larval cannibalism	Spodoptera frugiperda (fall armyworm); larval cannibalism. Honduras.	©Frank Peairs/Colorado State University/Bugwood.org - CC BY 3.0 US

Identity

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Preferred Scientific Name

Spodoptera frugiperda J.E. Smith

Preferred Common Name

fall armyworm

Other Scientific Names

Caradrina frugiperda
Laphygma frugiperda Guenee, 1852
Laphygma inepta Walker, 1856
Laphygma macra Guenee, 1852
Noctua frugiperda J.E. Smith
Phalaena frugiperda Smith & Abbot, 1797
Prodenia autumnalis Riley, 1870
Prodenia plagiata Walker, 1856
Prodenia signifera Walker, 1856
Trigonophora frugiperda Geyer, 1832

International Common Names

English: alfalfa worm; armyworm, fall; buckworm; budworm; corn budworm; corn leafworm; cotton leaf worm; daggy's corn worm; grass caterpillar; grass worm; maize budworm; overflow worm; rice caterpillar; southern armyworm; southern grassworm; wheat cutworm; whorlworm
Spanish: cogollero del maíz; grillo cogollero; gusano cogollero; gusano cogollero del maíz; gusano de la hierba; oruga del cogollo del maíz; oruga militar; oruga militar del maíz; oruga negra; oruga peladora de los pastos; palomilla del maíz
French: légionnaire d'automne

Local Common Names

Argentina: isoca militar tardia
Brazil: curuquere dos capinzais; curuquere dos milharais; lagarta do cartucho do milho; lagarta militar
Germany: Heerwurm
Mexico: gusano cogollero del maiz

English acronym

FAW

EPPO code

LAPHFR (Spodoptera frugiperda)

Taxonomic Tree

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Domain: Eukaryota
Kingdom: Metazoa
Phylum: Arthropoda
Subphylum: Uniramia
Class: Insecta
Order: Lepidoptera
Family: Noctuidae
Genus: Spodoptera
Species: Spodoptera frugiperda

Description

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Egg

The eggs are 0.4 mm in diameter and 0.3 mm in height; they are pale yellow or creamish at the time of oviposition and become light brown prior to eclosion. Egg maturity takes 2-3 days (20-30°C). Eggs are usually laid in masses of approximately 150-200 eggs which are laid in two to four layers deep on the surface of the leaf. The egg mass is usually covered with a protective, felt-like layer of grey-pink scales (setae) from the female abdomen. Up to 1000 eggs may be laid by each female. Eggs masses may be laid on the underside of the leaves, or on top of the leaves. In a few cases, particularly on very young crops, eggs may be laid on the stem.

Larva

Larvae are a light green to dark brown with longitudinal stripes. In the sixth instar, larvae can reach 4.5 cm long. Larvae have eight prolegs and a pair of prolegs on the last adbominal segment. On hatching they are green with black lines and spots, and as they grow they either remain green or become buff-brown and have black dorsal and spiracular lines. If crowded (by a high population density and food shortage) the final instar can be almost black in its armyworm phase. Large larvae are characterized by an inverted Y-shape in yellow on the head, black dorsal pinaculae with long primary setae (two each side of each segment within the pale dorsal zone) and four black spots arranged in a square on the last abdominal segment. There are usually six larval instars, occasionally five. A full description of the larvae is given in Crumb (1956). Levy and Habeck (1976) give diagnostic features, and colour plates are provided by King and Saunders (1984) and CIMMYT (2018).

Pupa

Pupae are shorter than mature larvae (1.3-1.5 cm in males and 1.6-1.7 cm in females in Mexico), and are shiny brown. Pupation normally occurs in the soil, but could also occur in reproductive parts such as mature maize ears. If the soil is too hard, larvae may web together leaf debris and other material to form a cocoon on the soil surface. Duration of the pupal stage is about 8 to 9 days during the summer, but reaches 20 to 30 days during cooler weather.

Adult Male

Male body length is 1.6 cm and wingspan 3.7 cm. The forewing is mottled (light brown, grey, straw) with a discal cell containing straw colour on three quarters of the area and dark brown on one quarter of the area with triangular white spots at the tip and near the centre of the wing.

Adult Female

Female body length is 1.7 cm and wingspan 3.8 cm. The forewings of females are less distinctly marked, ranging from a uniform greyish brown to a fine mottling of grey and brown. Hindwings are straw colour with a dark-brown margin. Adults are nocturnal, and are most active during warm, humid evenings. After a preoviposition period of 3 to 4 days, the female moth normally deposits most of her eggs during the first 4 to 5 days of life, but some oviposition occurs for up to 3 weeks. Duration of adult life is estimated to average about 10 days, with a range of about 7 to 21 days (Luginbill, 1928; Sparks, 1979).

Summary of Invasiveness

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The fall armyworm, *Spodoptera frugiperda*, is a lepidopteran pest that feeds in large numbers on the leaves, stems and reproductive parts of more than 350 plant species, causing major damage to economically important cultivated grasses such as maize, rice, sorghum, sugarcane and wheat but also other vegetable crops and cotton. Native to the Americas, it has been repeatedly intercepted at quarantine in Europe and was first reported from Africa in 2016 where it caused significant damage to maize crops. In 2018, *S. frugiperda* was first reported from the Indian subcontinent (Ganiger et al., 2018; Sharanabasappa Kalleshwaraswamy et al., 2018). It has since invaded Bangladesh, Thailand, Myanmar, China and Sri Lanka (IPPC, 2018b, 2019; FAO, 2019c). The ideal climatic conditions for fall armyworm present in many parts of Africa and Asia, and the abundance of suitable host plants suggests the pest can produce several generations in a single season, and is likely to lead to the pest becoming endemic.

Distribution

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S. frugiperda is native to tropical and subtropical regions of the Americas. The moth lives year-round from as far south as Argentina, to as far north as southern Florida and Texas (Nagoshi et al., 2012; Early et al., 2018). In 2016 it was reported for the first time from the African continent, in Nigeria, Sao Tomé, Benin and Togo (Goergen et al., 2016; IPPC, 2016). It has now been confirmed in more than 30 African countries (FAO, 2018). For further information on *S. frugiperda* in Africa, see CABI's Fall armyworm portal.

In 2018, *S. frugiperda* was reported from the Indian subcontinent (Ganiger et al., 2018; IITA, 2018; Sharanabasappa Kalleshwaraswamy et al., 2018), in Karnataka (ICAR-NBAIR, 2018a) and Andhra Pradesh (EPPO, 2018). The pest has also been reported in Bihar, Chhattisgarh, Gujarat, Maharashtra, Odisha, Tamil Nadu, Telangana and West Bengal (ICAR-NBAIR, 2018b; EPPO, 2019). A live tracking tool for fall armyworm in India has been developed by PEAT, CABI and ICRISAT: https://plantix.net/en/live/fall-armyworm. *S. frugiperda* has also been reported in Myanmar (IPPC, 2019a), Sri Lanka (FAO, 2019a), China (FAO, 2019b; FAO, 2019e), Bangladesh (FAO, 2019c), Thailand (IPPC, 2018b) and Korea Republic (IPPC, 2019b). There are preliminary reports of fall armyworm in Japan (IPPC, 2019d) and the Philippines (IPPC, 2019i). There is a preliminary report of *S. frugiperda* on the islands of Saibai and Erub in Torres Strait (IPPC, 2020).

Distribution Table

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The distribution in this summary table is based on all the information available. When several references are cited, they may give conflicting information on the status. Further details may be available for individual references in the Distribution Table Details section which can be selected by going to Generate Report.

Last updated: 07 Oct 2021

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	Notes
Africa							
Angola	Present		Introduced	2017	Invasive	FAO (2017a)	
Benin	Present		Introduced	2016	Invasive	IITA (2016)	
Botswana	Present		Introduced	2017	Invasive	FAO (2017a)	
Burkina Faso	Present, Widespread		Introduced	2017	Invasive	IPPC (2017a)	
Burundi	Present		Introduced	2017	Invasive	FAO (2017a)	
Cabo Verde	Present		Introduced	2017	Invasive	FAO (2017)	
Cameroon	Present, Localized		Introduced	2017	Invasive	IPPC (2017b)	
Central African Republic	Present		Introduced	2017	Invasive	FAO (2018)	
Chad	Present		Introduced	2017	Invasive	Day et al. (2017)	
Congo, Democratic Republic of the	Present		Introduced	2017	Invasive	IPAPEL-FAO (2017)	
Congo, Republic of the	Present		Introduced	2017	Invasive	FAO (2018)	Detected awaiting official reporting
Côte d'Ivoire	Present					FAO (2018)	
Egypt	Present, Localized					IPPC (2019d)	
Equatorial Guinea	Absent, Unconfirmed presence record(s)					EPPO (2021)	
Eritrea	Present					Ministry of Agriculture of the State of Eritrea (2018)	
Eswatini	Present, Localized		Introduced	2017	Invasive	IPPC (2017)	
Ethiopia	Present		Introduced	2017	Invasive	Day et al. (2017)	
Gabon	Present, Widespread		Introduced		Invasive	IPPC (2019)	
Gambia	Present		Introduced		Invasive	FAO (2017)	
Ghana	Present, Widespread		Introduced	2017	Invasive	Cock et al. (2017)	
Guinea	Present		Introduced	2017	Invasive	Day et al. (2017)	
Guinea-Bissau	Present		Introduced	2017	Invasive	FAO (2017)	
Kenya	Present		Introduced	2017	Invasive	CABI (Undated)	Original citation: Republic and of Kenya Ministry of Agriculture, Livestock & Fisheries (2017)
Liberia	Present		Introduced		Invasive	FAO (2018)	
Madagascar	Present		Introduced	2017	Invasive	FAO (2017)	

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	Notes
Malawi	Present		Introduced	2017	Invasive	Day et al. (2017)	
Mali	Present		Introduced		Invasive	FAO (2017)	
Mauritania	Present, Localized					EPPO (2020)	
Mayotte	Present, Localized					EPPO (2021)	
Mozambique	Present		Introduced	2017	Invasive	Day et al. (2017)	
Namibia	Present		Introduced	2017	Invasive	Day et al. (2017)	
Niger	Present		Introduced	2017	Invasive	Day et al. (2017)	
Nigeria	Present		Introduced	2016	Invasive	IITA (2016)	First reported in Jan. 2016 in the southwest, within a few months, also in northern Nigeria, Edo and additional southwest areas
Réunion	Present, Localized					EPPO (2021)	
Rwanda	Present		Introduced	2017	Invasive	Day et al. (2017)	
São Tomé and Príncipe	Present, Widespread		Introduced	2016	Invasive	IPPC (2016)	
Senegal	Present		Introduced	2017	Invasive	FAO (2017)	
Seychelles	Present		Introduced	2017	Invasive	FAO (2017)	
Sierra Leone	Present		Introduced	2017	Invasive	FAO (2017a)	
Somalia	Present		Introduced	2017	Invasive	FAO (2017)	
South Africa	Present		Introduced	2017	Invasive	Day et al. (2017)	
South Sudan	Present					FAO (2017)	
Sudan	Present		Introduced	2017	Invasive	Day et al. (2017)	South Sudan
Tanzania	Present		Introduced	2017	Invasive	Day et al. (2017)	
Togo	Present		Introduced	2016	Invasive	IITA (2016)	Kara and Plateau regions
Uganda	Present		Introduced	2017	Invasive	Day et al. (2017)	
Zambia	Present		Introduced	2017	Invasive	IPPC (2017c)	Preliminary report. CABI barcoded specimens.
Zimbabwe	Present		Introduced	2017	Invasive	CABI (Undated)	Original citation: FAO (2017)
Asia							
Bangladesh	Present					FAO (2019)	
Bhutan	Present					EPPO (2021)	
China	Present					FAO (2019c)	
-Anhui	Present					EPPO (2021)	
-Beijing	Present					EPPO (2021)	
-Chongqing	Present					FAO (2019d)	
-Fujian	Present					FAO (2019d)	
-Gansu	Present					EPPO (2021)	
-Guangdong	Present					FAO (2019d)	

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	Notes
-Guangxi	Present					FAO (2019d)	
-Guizhou	Present					FAO (2019d)	
-Hainan	Present					FAO (2019d)	
-Hebei	Present					EPPO (2021)	
-Henan	Present					FAO (2019d)	
-Hubei	Present					FAO (2019d)	
-Hunan	Present					FAO (2019d)	
-Jiangsu	Present					EPPO (2021)	
-Jiangxi	Present					FAO (2019d)	
-Ningxia	Present					EPPO (2021)	
-Shaanxi	Present					EPPO (2021)	
-Shandong	Present					EPPO (2021)	
-Shanghai	Present					EPPO (2021)	
-Shanxi	Present					EPPO (2021)	
-Sichuan	Present					FAO (2019d)	
-Yunnan	Present					FAO (2019c)	
-Zhejiang	Present					FAO (2019d)	
Hong Kong	Present					EPPO (2021)	
India	Present, Localized		Introduced			ICAR-NBAIR (2018)	
-Andhra Pradesh	Present, Localized		Introduced	2018		ICAR-NBAIR (2018a)	
-Arunachal Pradesh	Present					EPPO (2021)	
-Assam	Present					EPPO (2021)	
-Bihar	Present					EPPO (2019)	
-Chhattisgarh	Present					EPPO (2019)	
-Goa	Present					EPPO (2021)	
-Gujarat	Present					EPPO (2019)	
-Himachal Pradesh	Present					Ankita et al. (2020)	
-Jharkhand	Present					EPPO (2021)	
-Karnataka	Present, Localized		Introduced	2018		Ganiger et al. (2018)	
-Kerala	Present					Gavas Ragesh and Sanju Balan (2020)	
-Madhya Pradesh	Present		Introduced			Swamy et al. (2018)	
-Maharashtra	Present		Introduced	2018		ICAR-NBAIR (2018a)	
-Manipur	Present					EPPO (2021)	
-Meghalaya	Present					EPPO (2021)	
-Mizoram	Present					EPPO (2021)	

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	Notes
-Nagaland	Present					EPPO (2021)	
-Odisha	Present					EPPO (2019)	
-Rajasthan	Present					EPPO (2021)	
-Sikkim	Present					EPPO (2021)	
-Tamil Nadu	Present		Introduced	2018		ICAR-NBAIR (2018a)	
-Telangana	Present					FAO (2019d)	
-Tripura	Present					EPPO (2021)	
-Uttar Pradesh	Present					EPPO (2021)	
-West Bengal	Present					EPPO (2019)	
Indonesia	Present, Localized					IPPC (2019g)	Sumatra, Java, Kalimantan
-Java	Present, Localized					EPPO (2021)	
-Sumatra	Present, Localized					EPPO (2021)	
Israel	Present					EPPO (2020)	
Japan	Present, Transient under eradication					IPPC (2019c)	Preliminary report. Minamikyushu-City, Kagoshima-Prefecture
-Kyushu	Present, Transient under eradication					EPPO (2021)	
Jordan	Present, Localized			2020		IPPC (2020e)	Jordan valley
Laos	Present					FAO (2019b)	
Macau	Present					EPPO (2021)	
Malaysia	Present					CABI (Undated)	Present: under eradication; Original citation: IPPC (2019j)
Myanmar	Present					IPPC (2019a)	Present: subject to official control
Nepal	Present					Ratna et al. (2019)	
Pakistan	Present		Introduced	2019		Naeem-Ullah et al. (2019)	
Philippines	Present, Few occurrences					CABI (Undated)	Preliminary report; Original citation: IPPC (2019i)
South Korea	Present, Transient under eradication					IPPC (2020b)	
Sri Lanka	Present		Introduced			FAO (2019a)	
Syria	Present					Heinoun et al. (2021)	
Thailand	Present		Introduced	2018		IPPC (2018)	Present: subject to official control.
United Arab Emirates	Present					IPPC (2020a)	Preliminary status report is Present: under eradication.
Vietnam	Present					FAO (2019b)	
Yemen	Present					FAO (2018)	
Europe							

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	Notes
Finland	Absent, Confirmed absent by survey					EPPO (2021)	
Germany	Absent, Eradicated					EPPO (2021)	
Lithuania	Absent, Confirmed absent by survey					EPPO (2021)	
Netherlands	Absent, Confirmed absent by survey					NPPO of the Netherlands (2013)	Based on long-term annual surveys, 362 survey observations in 2012.
Slovenia	Absent					EPPO (2021)	
North America							
Anguilla	Present					EPPO (2021)	
Antigua and Barbuda	Present					EPPO (2021)	
Bahamas	Present					EPPO (2021)	
Barbados	Present					EPPO (2021)	
Belize	Present					EPPO (2021)	
Bermuda	Present					EPPO (2021)	
British Virgin Islands	Present					EPPO (2021)	
Canada	Present, Localized					EPPO (2021)	
-Manitoba	Present					EPPO (2021)	
-New Brunswick	Present					EPPO (2021)	
-Nova Scotia	Present					EPPO (2021)	
-Ontario	Present					Starratt and McLeod (1982)	
-Prince Edward Island	Present					EPPO (2021)	
-Quebec	Present					Martel et al. (1980)	
Cayman Islands	Present					EPPO (2021)	
Costa Rica	Present					EPPO (2021)	
Cuba	Present					EPPO (2021)	
Dominica	Present					EPPO (2021)	
Dominican Republic	Present					EPPO (2021)	
El Salvador	Present					EPPO (2021)	
Grenada	Present					EPPO (2021)	
Guadeloupe	Present					EPPO (2021)	
Guatemala	Present					EPPO (2021)	
Haiti	Present, Few occurrences					EPPO (2021)	
Honduras	Present					EPPO (2021)	
Jamaica	Present					EPPO (2021)	
Martinique	Present, Widespread					EPPO (2021)	
Mexico	Present, Widespread					Sifuentes A. (1978)	

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	Notes
Montserrat	Present					EPPO (2021)	
Nicaragua	Present					Huis (1981)	
Panama	Present					EPPO (2021)	
Puerto Rico	Present					EPPO (2021)	
Saint Kitts and Nevis	Present					EPPO (2021)	
Saint Lucia	Present					EPPO (2021)	
Saint Vincent and the Grenadines	Present					EPPO (2021)	
Trinidad and Tobago	Present					EPPO (2021)	
U.S. Virgin Islands	Present					EPPO (2021)	
United States	Present					Greathead and Greathead (1992)	
-Alabama	Present					EPPO (2021)	
-Arizona	Present					EPPO (2021)	
-Arkansas	Present					EPPO (2021)	
-California	Present					EPPO (2021)	
-Colorado	Present					EPPO (2021)	
-Connecticut	Present					EPPO (2021)	
-Delaware	Present					EPPO (2021)	
-Florida	Present					EPPO (2021)	
-Georgia	Present					EPPO (2021)	
-Illinois	Present					EPPO (2021)	
-Indiana	Present					EPPO (2021)	
-Iowa	Present					EPPO (2021)	
-Kansas	Present					EPPO (2021)	
-Kentucky	Present					EPPO (2021)	
-Louisiana	Present					EPPO (2021)	
-Maine	Present					EPPO (2021)	
-Maryland	Present					EPPO (2021)	
-Massachusetts	Present					EPPO (2021)	
-Michigan	Present					EPPO (2021)	
-Minnesota	Present					EPPO (2021)	
-Mississippi	Present					EPPO (2021)	
-Missouri	Present					EPPO (2021)	
-Montana	Present					EPPO (2021)	
-Nebraska	Present					EPPO (2021)	
-New Hampshire	Present					EPPO (2021)	
-New Jersey	Present					EPPO (2021)	
-New Mexico	Present					EPPO (2021)	

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	Notes
-New York	Present					EPPO (2021)	
-North Carolina	Present					EPPO (2021)	
-North Dakota	Present					EPPO (2021)	
-Ohio	Present					EPPO (2021)	
-Oklahoma	Present					EPPO (2021)	
-Pennsylvania	Present					EPPO (2021)	
-Rhode Island	Present					EPPO (2021)	
-South Carolina	Present					EPPO (2021)	
-South Dakota	Present					EPPO (2021)	
-Tennessee	Present					EPPO (2021)	
-Texas	Present					EPPO (2021)	
-Virginia	Present					EPPO (2021)	
-West Virginia	Present					EPPO (2021)	
-Wisconsin	Present					EPPO (2021)	
-Wyoming	Present					EPPO (2021)	
Oceania							
Australia	Present, Widespread		Introduced	2020		IPPC (2021a)	
-New South Wales	Present		Introduced	2020		IPPC (2021a)	
-Northern Territory	Present		Introduced	2020		IPPC (2021a)	
-Queensland	Present		Introduced	2020		IPPC (2021a)	
-Tasmania	Present		Introduced	2021		IPPC (2021a)	
-Victoria	Present		Introduced	2020		IPPC (2021a)	
-Western Australia	Present		Introduced	2020		IPPC (2021a)	
New Caledonia	Present, Localized			2020		IPPC (2021)	
Norfolk Island	Present		Introduced	2021		IPPC (2021a)	
Papua New Guinea	Present, Localized					EPPO (2020)	Jiwaka, Madang, Morobe, Western, Western highlands provinces
Solomon Islands	Present, Localized					IPPC (2021b)	Present: not widely distributed and under official
Timor-Leste	Present					EPPO (2020)	
South America							
Argentina	Present					EPPO (2021)	
Bolivia	Present					EPPO (2021)	
Brazil	Present					EPPO (2021)	
-Amapa	Present					EPPO (2021)	
-Amazonas	Present					EPPO (2021)	
-Bahia	Present					Soares and Silva (2003)	

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	Notes
-Ceara	Present					EPPO (2021)	
-Espirito Santo	Present					Pratissoli et al. (2007)	
-Goias	Present					EPPO (2021)	
-Maranhao	Present					EPPO (2021)	
-Mato Grosso	Present					EPPO (2021)	
-Mato Grosso do Sul	Present					EPPO (2021)	
-Minas Gerais	Present					EPPO (2021)	
-Para	Present					EPPO (2021)	
-Paraiba	Present					EPPO (2021)	
-Parana	Present					EPPO (2021)	
-Pernambuco	Present					EPPO (2021)	
-Piaui	Present					Souza et al. (2015)	
-Rio de Janeiro	Present					EPPO (2021)	
-Rio Grande do Norte	Present					Silva et al. (2000)	
-Rio Grande do Sul	Present					EPPO (2021)	
-Roraima	Present					EPPO (2021)	
-Santa Catarina	Present					EPPO (2021)	
-Sao Paulo	Present					EPPO (2021)	
-Tocantins	Present					Didonet et al. (2001)	
Chile	Present, Localized					EPPO (2021)	
Colombia	Present					EPPO (2021)	
Ecuador	Present, Widespread					EPPO (2021)	
French Guiana	Present					EPPO (2021)	
Guyana	Present					Rambajan (1981)	
Paraguay	Present					EPPO (2021)	
Peru	Present					EPPO (2021)	
Suriname	Present					EPPO (2021)	
Uruguay	Present, Widespread					EPPO (2021)	
Venezuela	Present					Solano et al. (2015)	Western

Risk of Introduction

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S. frugiperda is on the EPPO A1 list of quarantine pests and is intercepted occasionally in Europe on imported plant material (Seymour et al., 1985). From Africa alone, in 2017, two consignments containing fall armyworm were intercepted in Europe, and 17 interceptions were made in the first 8 months of 2018 from wide-ranging crops including *Capsicum*, *Coriandrum*, *Eryngium*, *Eustoma*, *Pisum*, *Rosa*, *Solanum* and *Zea mays* (EUROPHYT).

Phytosanitary Measures

Plants for planting should come from a place of production inspected and found free from the pest during the previous months. Directive 2000/29/EC listed FAW as a harmful organism whose introduction into and spread within all EU member states was banned, it not being present in any member state. Jeger et al. (2017) conducted a pest categorisation of fall armyworm, and concluded that it could be regarded as a 'Union quarantine pest'.

Habitat List

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Category	Sub-Category	Habitat	Presence	Status
Terrestrial	Terrestrial – Managed	Cultivated / agricultural land	Present, no further details	Harmful (pest or invasive)
		Protected agriculture (e.g. glasshouse production)	Present, no further details	Harmful (pest or invasive)
		Managed forests, plantations and orchards	Present, no further details	Harmful (pest or invasive)
		Managed grasslands (grazing systems)	Present, no further details	Harmful (pest or invasive)
		Industrial / intensive livestock production systems	Present, no further details	Harmful (pest or invasive)
		Disturbed areas	Present, no further details	Natural
		Rail / roadsides	Present, no further details	Natural
		Urban / peri-urban areas	Present, no further details	Natural
	Terrestrial - Natural / Semi-natural	Natural forests	Present, no further details	Natural
		Natural grasslands	Present, no further details	Natural
		Riverbanks	Present, no further details	Natural
		Wetlands	Present, no further details	Natural
		Scrub / shrublands	Present, no further details	Natural
		Arid regions	Present, no further details	Natural

Hosts/Species Affected

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S. frugiperda is a polyphagous pest which shows a definite preference for the Poaceae (Casmuz et al., 2010). It is most commonly recorded from wild and cultivated grasses; from maize, rice, sorghum and sugarcane. However, Montezano et al. (2018) have recently reported 353 host plant species based on a thorough literature review, and additional surveys in Brazil, from 76 plant families, principally Poaceae (106), Asteraceae (31) and Fabaceae (31).

Host Plants and Other Plants Affected

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Plant name	Family	Context	References
Abelmoschus esculentus (okra)	Malvaceae	Other	
Acalypha (Copperleaf)	Euphorbiaceae	Other	
Agrostis (bentgrasses)	Poaceae	Wild host	
Agrostis gigantea (black bent)	Poaceae	Other	
Agrostis stolonifera (creeping bentgrass)	Poaceae	Other	
Alcea rosea (Hollyhock)	Malvaceae	Other	
Allium	Liliaceae	Main	
Allium cepa (onion)	Liliaceae	Other	
Allium sativum (garlic)	Liliaceae	Other	
Amaranthus (amaranth)	Amaranthaceae	Other	
Amaranthus quitensis	Amaranthaceae	Other	
Amaranthus spinosus (spiny amaranth)	Amaranthaceae	Other	
Andropogon virginicus (broomsedge)	Poaceae	Wild host	
Arachis hypogaea (groundnut)	Fabaceae	Main	
Asclepias (Silkweed)	Asclepiadaceae	Other	
Asparagus officinalis (asparagus)	Liliaceae	Other	
Asplenium nidus (bird's nest fern)	Aspleniaceae	Other	
Atropa belladonna (deadly nightshade)	Solanaceae	Wild host	
Avena sativa (oats)	Poaceae	Other	
Avena strigosa (black oat)	Poaceae	Other	
Beta	Chenopodiaceae	Other	
Beta vulgaris (beetroot)	Chenopodiaceae	Other	
Beta vulgaris var. cicla	Chenopodiaceae	Other	
Beta vulgaris var. saccharifera (sugarbeet)	Chenopodiaceae	Main	
Brassica napus var. napus (rape)	Brassicaceae	Other	
Brassica oleracea (cabbages, cauliflowers)	Brassicaceae	Main	
Brassica oleracea var. botrytis (cauliflower)	Brassicaceae	Other	
Brassica oleracea var. capitata (cabbage)	Brassicaceae	Other	
Brassica oleracea var. viridis (collards)	Brassicaceae	Other	
Brassica rapa (field mustard)	Brassicaceae	Other	
Brassica rapa subsp. oleifera (turnip rape)	Brassicaceae	Other	
Brassica rapa subsp. rapa (turnip)	Brassicaceae	Main	
Brassicaceae (cruciferous crops)	Brassicaceae	Main	
Cajanus cajan (pigeon pea)	Fabaceae	Other	
Capsicum (peppers)	Solanaceae	Other	
Capsicum annuum (bell pepper)	Solanaceae	Main	
Capsicum frutescens (chilli)	Solanaceae	Other	
Carduus (thistle)	Asteraceae	Other	
Carex (sedges)	Cyperaceae	Wild host	
Carica papaya (pawpaw)	Caricaceae	Other	
Carya (hickories)	Juglandaceae	Other	
Carya illinoinensis (pecan)	Juglandaceae	Other	
Cenchrus incertus (Spiny burrgrass)	Poaceae	Wild host	

Plant name	Family	Context	References
Chenopodium album (fat hen)	Chenopodiaceae	Wild host	
Chenopodium quinoa (quinoa)	Chenopodiaceae	Other	
Chloris gayana (Rhodes grass)	Poaceae	Other	
Chrysanthemum (daisy)	Asteraceae	Other	
Chrysanthemum morifolium (chrysanthemum (florists'))	Asteraceae	Main	
Cicer arietinum (chickpea)	Fabaceae	Other	
Cichorium intybus (chicory)	Asteraceae	Other	
Citrullus lanatus (watermelon)	Cucurbitaceae	Other	
Citrus aurantium (sour orange)	Rutaceae	Other	
Citrus limon (lemon)	Rutaceae	Other	
Citrus reticulata (mandarin)	Rutaceae	Other	
Citrus sinensis (sweet orange)	Rutaceae	Other	
Codiaeum variegatum (garden croton)	Euphorbiaceae	Other	
Coffea arabica (arabica coffee)	Rubiaceae	Other	
Convolvulus (morning glory)	Convolvulaceae	Wild host	
Convolvulus arvensis (bindweed)	Convolvulaceae	Wild host	
Cucumis melo (melon)	Cucurbitaceae	Other	
Cucumis sativus (cucumber)	Cucurbitaceae	Main	
Cucurbita argyrosperma (silver-seed gourd)	Cucurbitaceae	Other	
Cucurbita maxima (giant pumpkin)	Cucurbitaceae	Other	
Cucurbitaceae (cucurbits)	Cucurbitaceae	Main	
Cydonia oblonga (quince)	Rosaceae	Other	
Cynara cardunculus (cardoon)	Asteraceae	Other	
Cynodon dactylon (Bermuda grass)	Poaceae	Wild host	
Cyperus rotundus (purple nutsedge)	Cyperaceae	Wild host	
Dactyloctenium aegyptium (crowfoot grass)	Poaceae	Wild host	
Dahlia pinnata (garden dahlia)	Asteraceae	Other	
Dianthus caryophyllus (carnation)	Caryophyllaceae	Main	
Digitaria (crabgrass)	Poaceae	Wild host	
Digitaria sanguinalis (large crabgrass)	Poaceae	Wild host	
Echinochloa colona (junglerice)	Poaceae	Other	
Echinochloa crus-galli (barnyard grass)	Poaceae	Wild host	
Eleusine indica (goose grass)	Poaceae	Wild host	
Elymus repens (quackgrass)	Poaceae	Wild host	
Eremochloa ophiuroides (centipedegrass)	Poaceae	Other	
Eriochloa punctata	Poaceae	Wild host	
Eryngium foetidum	Apiaceae	Other	
Eucalyptus	Myrtaceae	Other	
Eucalyptus camaldulensis (red gum)	Myrtaceae	Other	
Eucalyptus urophylla (Timor mountain gum)	Myrtaceae	Other	
Fagopyrum esculentum (buckwheat)		Other	
Festuca arundinacea (tall fescue)	Poaceae	Other	
Ficus	Moraceae	Other	
Fragaria ananassa (strawberry)	Rosaceae	Other	
Fragaria chiloensis (Chilean strawberry)	Rosaceae	Other	

Plant name	Family	Context	References
Fragaria vesca (wild strawberry)	Rosaceae	Other	
Gladiolus (sword lily)	Iridaceae	Other	
Gladiolus hybrids (sword lily)	Iridaceae	Other	
Glycine max (soyabean)	Fabaceae	Main	
Gossypium (cotton)	Malvaceae	Main	
Gossypium herbaceum (short staple cotton)	Malvaceae	Other	
Gossypium hirsutum (Bourbon cotton)	Malvaceae	Other	
Helianthus annuus (sunflower)	Asteraceae	Other	
Hevea brasiliensis (rubber)	Euphorbiaceae	Other	
Hibiscus cannabinus (kenaf)	Malvaceae	Other	
Hordeum vulgare (barley)	Poaceae	Other	
Ipomoea (morning glory)	Convolvulaceae	Other	
Ipomoea batatas (sweet potato)	Convolvulaceae	Main	
Ipomoea purpurea (tall morning glory)	Convolvulaceae	Wild host	
Lactuca sativa (lettuce)	Asteraceae	Other	
Lespedeza bicolor (bicolor lespedeza)	Fabaceae	Other	
Linum usitatissimum (flax)		Other	
Lolium multiflorum (Italian ryegrass)	Poaceae	Other	
Malpighia glabra (acerola)	Malpighiaceae	Other	
Malus domestica (apple)	Rosaceae	Other	
Mangifera indica (mango)	Anacardiaceae	Other	
Maranta (arrowroot)	Marantaceae	Other	
Medicago sativa (lucerne)	Fabaceae	Main	
Megathyrsus maximus (Guinea grass)	Poaceae	Other	
Melilotus albus (honey clover)	Fabaceae	Other	
Miscanthus × giganteus	Poaceae	Other	
Mucuna pruriens (velvet bean)	Fabaceae	Other	
Mucuna pruriens (velvet bean)	Fabaceae	Other	
Musa (banana)	Musaceae	Main	
Musa x paradisiaca (plantain)	Musaceae	Other	
Nicotiana tabacum (tobacco)	Solanaceae	Main	
Oryza sativa (rice)	Poaceae	Main	
Panicum (millets)	Poaceae	Other	
Panicum miliaceum (millet)	Poaceae	Other	
Panicum virgatum	Poaceae	Other	
Paspalum	Poaceae	Other	
Paspalum dilatatum (dallisgrass)	Poaceae	Other	
Paspalum distichum (knotgrass)	Poaceae	Other	
Paspalum fimbriatum	Poaceae	Other	
Paspalum notatum (Bahia grass)	Poaceae	Other	
Paspalum urvillei (Vasey grass)	Poaceae	Other	
Passiflora (passionflower)	Passifloraceae	Other	
Passiflora laurifolia	Passifloraceae	Other	
Pelargonium (pelargoniums)	Geraniaceae	Main	
Pennisetum clandestinum (Kikuyu grass)	Poaceae	Other	

Plant name	Family	Context	References
Pennisetum glaucum (pearl millet)	Poaceae	Other	
Phalaris canariensis (Canarygrass)	Poaceae	Other	
Phaseolus (beans)	Fabaceae	Main	
Phaseolus lunatus (lima bean)	Fabaceae	Other	
Phaseolus vulgaris (common bean)	Fabaceae	Main	
Phleum pratense (timothy grass)	Poaceae	Other	
Pinus (pines)	Pinaceae	Other	
Pinus caribaea (Caribbean pine)	Pinaceae	Other	
Piper (pepper)	Piperaceae	Other	
Pisum sativum (pea)	Fabaceae	Other	
Platanus occidentalis (sycamore)	Platanaceae	Other	
Plumeria (frangipani)	Apocynaceae	Other	
Plumeria rubra (red frangipani)	Apocynaceae	Other	
Poa annua (annual meadowgrass)	Poaceae	Other	
Poa pratensis (smooth meadow-grass)	Poaceae	Other	
Poaceae (grasses)	Poaceae	Main	
Portulaca oleracea (purslane)	Portulacaceae	Wild host	
Prunus persica (peach)	Rosaceae	Other	
Psidium guajava (guava)	Myrtaceae	Other	
Pueraria montana var. lobata (kudzu)	Fabaceae	Other	
Pyrus communis (European pear)	Rosaceae	Other	
Raphanus sativus (radish)	Brassicaceae	Other	
Ricinus communis (castor bean)	Euphorbiaceae	Other	
Rosa (roses)	Rosaceae	Other	
Saccharum officinarum (sugarcane)	Poaceae	Main	
Schlumbergera truncata (christmas cactus)	Cactaceae	Other	
Secale cereale (rye)	Poaceae	Other	
Sesamum indicum (sesame)	Pedaliaceae	Other	
Setaria italica (foxtail millet)	Poaceae	Other	
Setaria parviflora (knotroot foxtail)	Poaceae	Other	
Setaria viridis (green foxtail)	Poaceae	Other	
Solanum (nightshade)	Solanaceae	Wild host	
Solanum lycopersicum (tomato)	Solanaceae	Main	
Solanum melongena (aubergine)	Solanaceae	Main	
Solanum tuberosum (potato)	Solanaceae	Main	
Sorghum	Poaceae	Other	
Sorghum bicolor (sorghum)	Poaceae	Main	
Sorghum caffrorum	Poaceae	Other	
Sorghum halepense (Johnson grass)	Poaceae	Other	
Sorghum sudanense (Sudan grass)	Poaceae	Other	
Spinacia oleracea (spinach)	Chenopodiaceae	Main	
Tanacetum cinerariifolium (Pyrethrum)		Other	
Taraxacum officinale complex (dandelion)	Asteraceae	Wild host	
Terminalia catappa (Singapore almond)	Combretaceae	Other	
Trifolium (clovers)	Fabaceae	Main	

Plant name	Family	Context	References
Trifolium incarnatum (Crimson clover)	Fabaceae	Other	
Trifolium pratense (red clover)	Fabaceae	Other	
Trifolium repens (white clover)	Fabaceae	Other	
Triticum (wheat)	Poaceae	Other	
Triticum aestivum (wheat)	Poaceae	Other	
turfgrasses		Other	
Urochloa	Poaceae	Wild host	
Urochloa decumbens (signal grass)	Poaceae	Wild host	
Urochloa mutica (para grass)	Poaceae	Wild host	
Urochloa ramosa (browntop millet)	Poaceae	Wild host	
Urochloa texana	Poaceae	Wild host	
Vaccinium (blueberries)	Ericaceae	Other	
Vaccinium corymbosum (blueberry)	Ericaceae	Other	
Vicia faba (faba bean)	Fabaceae	Other	
Vigna unguiculata (cowpea)	Fabaceae	Other	
Vigna unguiculata subsp. unguiculata	Fabaceae	Other	
Viola (violet)	Violaceae	Other	
Vitis (grape)	Vitaceae	Other	
Vitis vinifera (grapevine)	Vitaceae	Other	
Wisteria sinensis (Chinese wisteria)	Fabaceae	Other	
Xanthium strumarium (common cocklebur)	Asteraceae	Wild host	
Zea mays (maize)	Poaceae	Main	
Zea mays subsp. mays (sweetcorn)	Poaceae	Main	
Zea mays subsp. mexicana (teosinte)	Poaceae	Other	
Zingiber officinale (ginger)	Zingiberaceae	Main	
Zoysia	Poaceae	Other	

Growth Stages

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Flowering stage, Fruiting stage, Seedling stage, Vegetative growing stage

Symptoms

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Seedlings are fed upon within the whorl. Larger larvae can cut the base of the plant. Mature plants suffer attack on reproductive structures. On tomato plants, buds and growing points may be eaten and fruits pierced. Maize leaves are eaten and the whorl (funnel) may be a mass of holes, ragged edges and larval frass. Young larvae skeletonize the leaf lamina in a typical 'window-pane' damage. 'Window-paning' is the most common damage symptom at early whorl; however, this is sometimes indistinguishable from damage that is due to other stem borers. Usually many young larvae will be present on the same plant, but normally one or two older larvae may be found on a single plant, as others will migrate and feed on neighbouring plants. Later larval instars make larger holes, causing ragged whorl leaves, and produce sawdust-like larval droppings, while fresh feeding produces big lumps. Badly infested fields may look as if they have been hit by a severe hailstorm. Fall armyworm can also destroy silks and developing tassels, thereby limiting fertilization of the ear. Maize plants may have the cobs attacked by larvae boring through the kernels. Damage to cobs may lead to fungal infection and aflatoxins, and loss of grain quality. At high densities, large larvae may act as armyworms and disperse in swarms, but they often remain in the locality on wild grasses, if available.

List of Symptoms/Signs

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Sign	Life Stages	Type
Fruit / external feeding		
Fruit / internal feeding		
Growing point / external feeding		
Growing point / internal feeding; boring		
Inflorescence / external feeding		
Leaves / external feeding		
Stems / external feeding		
Whole plant / cut at stem base		

Biology and Ecology

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Eggs are laid at night on the leaves of the host, stuck to the lower surface of the lower part of the lower leaves, in tight clusters of 100-300 and sometimes in two layers, usually covered with a protective layer of abdominal bristles. When moth populations are high, the eggs may be laid higher up the plants, on top of the leaves or on nearby vegetation. Some reports suggest that heavy rains are important in breaking the life-cycle of fall armyworm, by washing off the eggs from the leaves onto the ground where they may be predated upon or if they hatched, they are unlikely to move on the soil to a nearby a food source. Hatching requires 2-10 days (usually 3-5). The mortality rate following emergence may be high in some cases due to climatic factors and attack by predators, parasitoids and pathogens. The young larvae migrate to the whorl; the first two instars feed gregariously on the underside or the top of the young leaves causing a characteristic skeletonizing or 'windowing' effect. In the second and third instar stages, larvae are often cannibalistic and thus one or two larvae per whorl is usual. The rate of larval development through the six instars is controlled by a combination of diet and temperature conditions, and usually takes 14-21 days. Larger larvae are nocturnal unless they enter the armyworm phase when they swarm and disperse, seeking other food sources. Pupation takes place inside a loose cocoon in an earthen cell but has also been observed in the kernels of the maize cob, or rarely between leaves on the host plant, and 9-13 days are required for development. Adults emerge at night, and they typically use their natural pre-oviposition period of 3-4 days to fly for many kilometres before they settle to oviposit, sometimes migrating for long distances. In the migratory habit, moths can migrate over 500 km (300 miles) before oviposition. The female normally deposits most of her eggs during the first 4-5 days of life, but some oviposition continues to occur for up to 3 weeks. On average, adults live for 12-14 days.

A threshold temperature of 10.9°C and 559 day-degrees C is required for development. Sandy-clay or clay-sand soils are suitable for pupation and adult emergence. Emergence in sandy-clay and clay-sand soils was directly proportional to temperature and inversely proportional to humidity. Above 30°C the wings of adults tend to be deformed. Pupae require a threshold temperature of 14.6°C and 138 day-degrees C to complete their development (Ramirez-Garcia et al., 1987).

S. frugiperda is a tropical species adapted to the warmer parts of the New World; the optimum temperature for larval development is reported to be 28°C, but it is lower for both oviposition and pupation. In the tropics, breeding can be continuous with four to six generations per year, but in northern regions only one or two generations develop; at lower temperatures, activity and development cease, and when freezing occurs all stages are usually killed. In the USA, *S. frugiperda* usually overwinters only in southern Texas and Florida. In mild winters, pupae survive in more northerly locations.

Genetic differentiation of fall armyworm

Fall armyworm occurs in two races: a ‘rice strain’ (R strain) and a ‘corn strain’ (C strain) (Lu and Adang, 1996; Lewter et al., 2006; Nagoshi et al., 2007); the former is thought to preferentially feed on rice and various pasture grasses and the latter on maize, cotton and sorghum. The strains are morphologically identical, but can be distinguished by molecular techniques. Recent evidence shows that the diversity of fall armyworm that invaded Africa is greater than previously thought, including a haplotype that has not yet been observed in the Western Hemisphere (Nagoshi et al., 2018). Analyses of South African specimens indicate corn and rice strains are both present (Jacobs et al., 2018). In Uganda, fall armyworm populations were found to consist of two sympatric sister species of maize-preferred and rice-preferred strains (Otim et al., 2018). There have been some attempts to establish the origin of these strains, and evidence from Ghana (Cock et al., 2017) and Togo (Nagoshi et al., 2018) suggests that the populations are most similar to that found in the Caribbean region and the eastern coast of the USA.

Air Temperature

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Parameter	Lower limit	Upper limit
Absolute minimum temperature (ºC)	8.2	
Mean annual temperature (ºC)	17	35
Mean maximum temperature of hottest month (ºC)	30	35
Mean minimum temperature of coldest month (ºC)	7	17

Rainfall

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Parameter	Lower limit	Upper limit	Description
Dry season duration	3	7	number of consecutive months with <40 mm rainfall
Mean annual rainfall	0	400	mm; lower/upper limits

Notes on Natural Enemies

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Efforts were made to introduce the egg parasitoid, *Telenomus remus*, into countries where it had not already been found. These introductions have been credited with reducing the numbers of this and other pest *Spodoptera* occuring alongside it (Cock, 1985).

Natural enemies

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Natural enemy	Type	Life stages	Specificity	References	Biological control in	Biological control on
Agelaius phoeniceus	Predator					
Alabagrus stigma	Parasite	Arthropods|Larvae				
Aleiodes laphygmae	Parasite	Arthropods|Larvae			Honduras	
Alveoplectrus corumbae	Parasite					
Archytas apicifer	Parasite	Arthropods|Larvae				
Archytas incertus	Parasite	Arthropods|Larvae			Brazil; Sao Paulo	maize
Archytas marmoratus	Parasite	Arthropods|Larvae; Arthropods|Pupae			Honduras	maize; sorghum
Bacillus cereus	Pathogen	Arthropods|Larvae				
Bacillus thuringiensis	Pathogen	Arthropods|Larvae				
Bacillus thuringiensis alesti	Pathogen	Arthropods|Larvae				
Bacillus thuringiensis darmstadiensis	Pathogen	Arthropods|Larvae				
Bacillus thuringiensis galleriae	Pathogen	Arthropods|Larvae				
Bacillus thuringiensis kurstaki	Pathogen	Arthropods|Larvae				
Bacillus thuringiensis thuringiensis	Pathogen	Arthropods|Larvae				
Bacillus thuringiensis tolworthi	Pathogen	Arthropods|Larvae				
Baculovirus spodoptera	Pathogen					
Balaustium putmani	Predator					
Beauveria bassiana	Pathogen	Eggs; Arthropods|Larvae		Komivi et al. (2019)	Kenya	
Brachymeria ovata	Parasite	Arthropods|Pupae				
Calleida decora	Predator	Arthropods|Larvae				
Calosoma alternans	Predator	Arthropods|Larvae				
Calosoma sayi	Predator	Arthropods|Larvae				
Campoletis chlorideae	Parasite			Shylesha et al. (2018)	Barbados, India	maize
Campoletis flavicincta	Parasite	Arthropods|Larvae		Silva et al. (2012)	Brazil; Sao Paulo	maize
Campoletis grioti	Parasite					
Campoletis oxylus						
Campoletis sonorensis	Parasite				Honduras	maize; sorghum
Carabidae	Predator	Arthropods|Larvae; Arthropods|Pupae				
Charops ater	Parasite	Arthropods|Larvae		Sisay et al. (2018)	Kenya, Tanzania	maize
Chelonus curvimaculatus	Parasite	Eggs; Arthropods|Larvae			Kenya	
Chelonus formosanus	Parasite	Arthropods|Larvae			Barbados; Trinidad and Tobago	maize
Chelonus insularis	Parasite	Eggs; Arthropods|Larvae			Brazil; Sao Paulo; Honduras	maize; sorghum
Coccygidium luteum	Parasite	Arthropods|Larvae		Sisay et al. (2018)	Kenya; Tanzania	maize
Cotesia icipe	Parasite	Arthropods|Larvae		Sisay et al. (2018)	Ethiopia; Kenya	
Cotesia marginiventris	Parasite	Arthropods|Larvae			Barbados; Brazil; Sao Paulo; Honduras; Trinidad	maize
Cotesia ruficrus	Parasite	Arthropods|Larvae			Trinidad and Tobago	

Natural enemy	Type	Life stages	Specificity	References	Biological control in	Biological control on
Cryptus albitarsis	Parasite					
Diapetimorpha introita	Parasite					
Doru luteipes	Predator					
Doru taeniatum	Predator					
Ectatomma ruidum	Predator					
Eiphosoma vitticolle	Parasite				Brazil; Sao Paulo; Honduras	maize
Entomophaga aulicae	Pathogen					
Erynia radicans	Pathogen				Venezuela	maize
Euplectrus comstockii	Parasite					
Euplectrus platyhypenae	Parasite	Arthropods|Larvae			Guyana; St Kitts Nevis	
Forficula	Predator	Arthropods|Larvae		Shylesha et al. (2018)	India	
Geocoris punctipes	Predator					
Glabromicroplitis croceipes	Parasite	Arthropods|Larvae				
Glyptapanteles creatonoti	Parasite	Arthropods|Larvae		Shylesha et al. (2018)	India	
Granulosis virus	Pathogen	Arthropods|Larvae				
Hyposoter annulipes	Parasite					
Labidura riparia	Predator					
Lespesia affinis	Parasite	Arthropods|Larvae				
Lespesia archippivora	Parasite	Arthropods|Larvae			Brazil; Sao Paulo; Honduras	maize; sorghum
Limonethe spodopterae	Parasite					
Lixophaga diatraeae	Parasite	Arthropods|Larvae				
Metarhizium anisopliae	Pathogen	Eggs; Arthropods|Larvae			Kenya	
Meteorus autographae	Parasite	Arthropods|Larvae				
Meteorus laphygmae	Parasite	Arthropods|Larvae				
Microchelonus heliopae	Parasite	Eggs; Arthropods|Larvae			Barbados	maize
Microplitis manilae	Parasite	Arthropods|Larvae				
Microplitis rufiventris	Parasite	Arthropods|Larvae				
Nabis capsiformis	Predator					
Noctuidonema guyanense	Parasite					
Nomuraea rileyi	Pathogen	Arthropods|Larvae			Nicaragua; Venezuela, India	maize
Nucleopolyhedrosis virus	Pathogen	Arthropods|Larvae				
Ophion flavidus	Parasite				Brazil; Sao Paulo; Honduras	maize; sorghum
Orius insidiosus	Predator					
Paecilomyces fumosoroseus	Pathogen					
Palexorista zonata	Parasite	Arthropods|Larvae		Sisay et al. (2018)	Ethiopia; Kenya	maize
Podisus connexivus	Predator					
Podisus maculiventris	Predator					
Solenopsis invicta	Predator					
Spilochalcis chapadae	Parasite					

Natural enemy	Type	Life stages	Specificity	References	Biological control in	Biological control on
Spodoptera frugiperda multiple nucleopolyhedrovirus	Pathogen	Arthropods|Larvae		Behle and Popham (2012); Gómez et al. (2013); Haase et al. (2015)		
Steinernema carpocapsae	Parasite	Arthropods|Larvae				
Steinernema feltiae	Parasite					
Steinernema riobravis	Parasite					
Stelopolybia pallipes	Predator					
Sycanus indagator	Predator					
Telenomus remus	Parasite	Eggs			Barbados; Benin; Bermuda; Côte d'Ivoire; Florida; Guyana; Kenya; Niger; South Africa; Suriname; Trinidad and Tobago; Venezuela	maize; vegetables
Temelucha difficilis	Parasite					
Trichogramma achaeae	Parasite	Eggs			Barbados	maize
Trichogramma chilotraeae	Parasite	Eggs			Barbados	maize
Trichogramma pretiosum	Parasite	Eggs				
Trichogramma rojasi	Parasite	Eggs		Camera et al. (2010)		
Trichospilus pupivora	Parasite				Barbados	maize
Vairimorpha necatrix	Pathogen					
Winthemia rufiventris	Parasite	Arthropods|Larvae				

Means of Movement and Dispersal

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S. frugiperda is a regular annual migrant in the Americas, dispersing throughout the USA and flying into southern Canada virtually every summer (Westbrook et al., 2016). It is suggested that, in this species, migration has evolved as a major component in the life history strategy. The use of the pre-oviposition (maturation) period for widespread dispersal seems to be very effective. In the USA, adult moths have been recorded using a low-level jet stream, which took them from Mississippi to Canada in 30 h.

Larvae frequently act as armyworms in late summer or early autumn and local dispersal is thus effected successfully, which helps to reduce larval mortality.

In most years larvae arrive in Europe carried by air-freight on vegetables or fruit from the New World; sometimes they are also intercepted on herbaceous ornamentals (Seymour et al., 1985). A useful review of this topic was produced by Johnson (1987).

The rapid spread of fall armyworm where it has recently invaded in Africa has been attributed to the strong flight capacity of the insect. The rapid spread to the Indian Ocean Islands and to Asia is harder to explain by natural flight, so it is possible that the frequent flights to those countries could have played a part. Cock et al. (2017) concluded that potential pathways of spread included unaided dispersal by wind-assisted flight, as contaminants of traded commodities, and as stowaways on or in aircraft. Wind-assisted flight alone might not have been sufficient for fall armyworm to cross the Atlantic or the Indian Ocean, but once it arrived, all the pathways listed could have occurred. It is still not clear whether there were multiple introduction events, or a single event involving multiple individuals.

Pathway Causes

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Cause	Notes	Long Distance	Local	References
Crop production		Yes	Yes	
Cut flower trade		Yes	Yes	
Horticulture		Yes	Yes	

Pathway Vectors

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Vector	Notes	Long Distance	Local	References
Plants or parts of plants		Yes	Yes	Seymour et al. (1985)
Bulk freight or cargo	potential pathway	Yes		Cock et al. (2017)
Aircraft	potential pathway	Yes		Cock et al. (2017)
Wind		Yes	Yes	Johnson (1987)

Plant Trade

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Plant parts liable to carry the pest in trade/transport	Pest stages	Borne internally	Borne externally	Visibility of pest or symptoms
Flowers/Inflorescences/Cones/Calyx	arthropods/eggs; arthropods/larvae	Yes	Yes	Pest or symptoms not visible to the naked eye but usually visible under light microscope
Fruits (inc. pods)	arthropods/eggs; arthropods/larvae	Yes	Yes	Pest or symptoms not visible to the naked eye but usually visible under light microscope
Leaves	arthropods/eggs; arthropods/larvae	Yes	Yes	Pest or symptoms not visible to the naked eye but usually visible under light microscope
Seedlings/Micropropagated plants	arthropods/eggs; arthropods/larvae	Yes	Yes	Pest or symptoms not visible to the naked eye but usually visible under light microscope
Stems (above ground)/Shoots/Trunks/Branches	arthropods/eggs	Yes		Pest or symptoms usually invisible

Plant parts not known to carry the pest in trade/transport
Bark
Bulbs/Tubers/Corms/Rhizomes
Growing medium accompanying plants
Roots
True seeds (inc. grain)
Wood

Impact Summary

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Category	Impact
Economic/livelihood	Negative
Environment (generally)	Negative

Impact: Economic

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S. frugiperda is found widely throughout the warmer parts of the New World. Damage results from leaf-eating and healthy plants usually recover quite quickly, but a large pest population can cause defoliation and resulting yield losses; the larvae then migrate to adjacent areas in true armyworm fashion.

Left unmanaged, or in the absence of natural biological control, fall armyworm can cause significant yield loss in maize and other crops. There are many variables to consider in determining the potential yield loss due to fall armyworm infestation. In general, how the crop responds to fall armyworm infestation is highly dependent on the population level of the pest and the timing of infestation, natural enemies and pathogen levels that can help to naturally regulate the populations, and the health and vigour of the maize plant (nutritional and moisture status). Baudron et al. (2019) have reported maize infestation of between 26.4 and 55.9% and impact on yield of 11.57%. Other authors have reported leaf, silk and tassel damage levels ranging between 25 and 50% and grain yield decrease of 58% (Chimweta et al., 2019). In Nicaragua, van Huis (1981) found a 33% increase in maize yield when plants were protected with insecticide. Infestations during the mid- to late-whorl stage of maize development caused yield losses of 15-73% when 55-100% of the plants were infested with *S. frugiperda* (Hruska and Gould, 1997). Caterpillars of *S. frugiperda* appear to be much more damaging to maize in West and Central Africa than most other African *Spodoptera* species (IITA, 2016).

Risk and Impact Factors

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Invasiveness
- Invasive in its native range
- Proved invasive outside its native range
- Has a broad native range
- Abundant in its native range
- Highly adaptable to different environments
- Is a habitat generalist
- Tolerates, or benefits from, cultivation, browsing pressure, mutilation, fire etc
- Pioneering in disturbed areas
- Tolerant of shade
- Capable of securing and ingesting a wide range of food
- Highly mobile locally
- Fast growing
- Has high reproductive potential
- Has high genetic variability

Impact outcomes
- Altered trophic level
- Damaged ecosystem services
- Ecosystem change/ habitat alteration
- Host damage
- Increases vulnerability to invasions
- Monoculture formation
- Negatively impacts agriculture
- Negatively impacts cultural/traditional practices
- Negatively impacts livelihoods
- Damages animal/plant products
- Negatively impacts trade/international relations

Impact mechanisms
- Herbivory/grazing/browsing
- Interaction with other invasive species
- Rapid growth

Likelihood of entry/control
- Highly likely to be transported internationally accidentally
- Difficult/costly to control

Detection and Inspection

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Detection is facilitated by searching fields for leaf feeding damage and by pheromone traps.

Similarities to Other Species/Conditions

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Larvae of *S. frugiperda* are distinct in their aggressive feeding behaviour and dark coloration.

Adults of *S. frugiperda* can be confused with those of *S. exempta* and *S. littoralis*. In *S. frugiperda* the veins of the hindwing are brown and distinct, and in the male forewing the pale orbicular stigma has a pronounced pale 'tail'; distally. In the male genitalia the valve is almost rectangular and there is no marginal notch at the position of the tip of the harpe; the female bursa lacks a signum. In Africa it can also be confused with *S. exigua* (IITA, 2016). An EPPO standard provides guidance for the identification of *S. littoralis*, *S. litura*, *S. frugiperda* and *S. eridania* (OEPP/EPPO, 2015); Brown and Dewhurst (1975) give details of the African species of *Spodoptera*, and Todd and Poole (1980) give keys to moths of the genus *Spodoptera* in the Western Hemisphere.

Prevention and Control

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Due to the variable regulations around (de)registration of pesticides, your national list of registered pesticides or relevant authority should be consulted to determine which products are legally allowed for use in your country when considering chemical control. Pesticides should always be used in a lawful manner, consistent with the product's label.

Introduction

The literature on this pest is extensive (Ashley et al., 1989). This is in part due to the importance of maize, the importance of lepidopteran pests, the quest for alternative control methods following the development of insect resistance to pesticides, and the development of host-plant resistance breeding programmes. On maize, if 5% of seedlings are cut or 20% of whorls of small plants (during the first 30 days) are infested, it is recommended that an insecticide be applied (King and Saunders, 1984); on sorghum the pest threshold level is regarded as one (or two) larvae per leaf whorl and two per head (Pitre, 1985).

Cultural Control

Control is largely achieved in the northern range through a winter kill by exposing larvae and pupae within the upper soil surface. Freezing temperatures cause high larval mortality. Therefore, clean cultivation and weeding are recommended. Some locally adaptable methods have also been tried such as soil, charcoal, ash, detergents, paraffin and engine oil. Various plant extracts are often included, such as chilli, neem, *Tephrosia*, *Tithonia*, *Lantana* and garlic. Handpicking egg masses and caterpillars has been tried in Africa. The efficacy of these methods is not well documented.

Agro-ecological options

Harrison et al. (2019) have reviewed evidence for the efficacy of potential agro-ecological measures for controlling fall armyworm. These include (i) sustainable soil fertility management, especially measures that maintain or restore soil organic carbon; (ii) intercropping with appropriately selected companion plants; and (iii) diversifying the farm environment through management of (semi)natural habitats at multiple spatial scales. The 'push-pull' system has been shown to reduce fall armyworm damage due to various pests in maize (Midega et al., 2018). A study in Uganda showed that intercropping maize with food legume crops can reduce fall armyworm damage levels by 30% with bean, 21% with soyabean and 31% with groundnut (Hailu et al., 2018).

Biological Control

A large number of parasitic Hymenoptera, acting as larval parasitoids, have been reared from *S. frugiperda*, and many predators are recorded including recent work by Molina-Ochoa et al. (2003), Hay-Roe et al. (2016), Meagher et al. (2016), Birhanu Sisay et al. (2018), Shylesha et al. (2018) and Kenis et al. (2019); it appears that natural controls are of considerable importance. Natural levels of larval parasitism are often very high (20-70%), mostly by braconid wasps. Some 10-15% of larvae are often killed by pathogens.

The compound N-(17-hydroxylinolenoyl)-L-glutamine called volicitin was isolated from oral secretions of *Spodoptera exigua* larvae. When applied to damaged leaves of maize seedlings, volicitin induced the seedlings to emit volatile compounds that attracted females of the parasitoid *Cotesia marginiventris*. Mechanical damage of the leaves, without application of this compound, did not trigger release of the same blend of volatiles. Volicitin appears to regulate tritrophic interactions among plants, insect herbivores and natural enemies of *S. exigua* (Alborn et al., 1997).

Biopesticides

Virus-based insecticides, which are mostly in the Baculovirus group, such as the multiple nucleopolyhedrovirus (SfMNPV) have potential for use in the management of fall armyworm (Behle and Popham, 2012; Gómez et al., 2013; Haase et al., 2015). They are highly host specific, non-pathogenic to beneficial insects and other non-target organisms, and are attractive candidates for integrated pest management. SfMNPV is specific to only fall armyworm. The pest is infected by ingesting the baculovirus. The symptoms of Baculovirus infection include appearance of blemishes, yellowing of the skin, and decline in feeding.

Metarhizium anisopliae and *Beauveria bassiana* have also shown efficacy against eggs and second-instar larvae of fall armyworm (Komivi et al., 2019). *B. bassiana* caused moderate mortality of 30% to second-instar larvae. *M. anisopliae* caused egg mortalities of 79.5-87.0% under laboratory conditions. Cumulative mortality of eggs and neonates with *M. anisopliae* reached as high as 96% with some fungal isolates. Bateman et al. (2018) reviewed products registered in 30 countries, 11 in the fall armyworm native range and 19 in Africa, and 50 biopesticide active ingredients were identified for use on this pest.

Botanicals

Azadirachtin (neem) is effective against fall armyworm. Oxymatrine and matrine (found in *Sophora* spp.) are reported to be effective against fall armyworm in the field and laboratory bioassays, respectively, in the Americas. Pyrethrins (from *Chrysanthemum cinerariaefolium*, formerly Pyrethrum) are effective against fall armyworm and registered in many countries, but have non-target risks that require mitigation. In Mexico, recent studies have shown that extracts of *Couroupita guianensis* and *Myrtillocactus geometrizans* could be good candidates for the control of

Spodoptera due to their larvicidal activity. Also, extracts from *Synedrella nodiflora* and *Lupinus stipulatus* have shown to have biological effects on mature insects of the genus *Spodoptera*.

Host-Plant Resistance

Spodoptera spp. resistance breeding programmes have developed field crop varieties with improved resistance, one example being maize (Mihm et al., 1988). One resistance mechanism that appears to be operating in maize is increased leaf toughness vis-à-vis a thicker epidermis (Davis et al., 1995).

Transgenic maize containing genes encoding delta-endotoxins from *Bacillus thuringiensis kurstaki* have been commercialized in the USA and Brazil. Vegetative insecticidal proteins (vip) have been isolated from *Bacillus thuringiensis* (Bt) during the vegetative phase of growth which show a wide spectrum of activities against lepidopteran pests, especially *Spodoptera* spp. (Estruch et al., 1996). *Spodoptera* spp. appear to be controlled by these toxins, but the development of resistance is a concern (Moar et al., 1995). Field-evolved resistance to the Bt maize expressing the Cry1Ab protein is reducing it efficacy in Brazil (Omoto et al., 2016). Fatoretto et al. (2017) reported that most Bt maize hybrids lost their ability to control fall armyworm within 3 years of introduction in Brazil.

Chemical Control

In some areas resistance to insecticides may be widespread and control can be difficult (Pitre, 1985). Recommended insecticides for *Spodoptera* spp. include esfenvalerate, carbaryl, chlorpyrifos, malathion, permethrin, and lamba-cyhalothrin (Anon., 1997). Togola et al. (2018) showed that five insecticide compounds used against fall armyworm (cypermethrin, deltamethrin, lambda-cyhalothrin, permethrin, and chorpyrifos) remained in the soil.

Pheromonal Control

The sex pheromone for *S. frugiperda* contains (Z)-9-Tetradecenyl acetate (Z-9-14:OAca) which is common to *Trichoplusia ni*, *Spodoptera exigua* and *Agrotis ipsilon exigua* (Klun et al., 1996). Mating disruption my be possible given the successes observed for S. exigua in which (9Z,12E)-9,12-tetradecadienyl acetate released at high concentrations, caused mating disruption in tomato, lucerne and cotton fields (Shorey et al., 1994).

IPM Programmes

Integrated control of *S. frugiperda* has been facilitated through cultivation practices to destroy overwintering sites, improved varieties with resistance to leaf feeding through conventional mechanisms or the introduction of Bt crops. Biological controls are prevalent and should be encouraged through reduced spaying of insecticides. CIMMYT (2018) have published a technical guide for IPM of S. frugiperda in Africa. CABI has also produced a manual for the training on farmers on how to use IPM in the management of fall armyworm.

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Contributors

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24/05/19 Review by:

Ivan Rwomushana, CABI Africa, Canary Bird, 673 Limuru Road, Muthaiga, Nairobi, Kenya.

Distribution Maps

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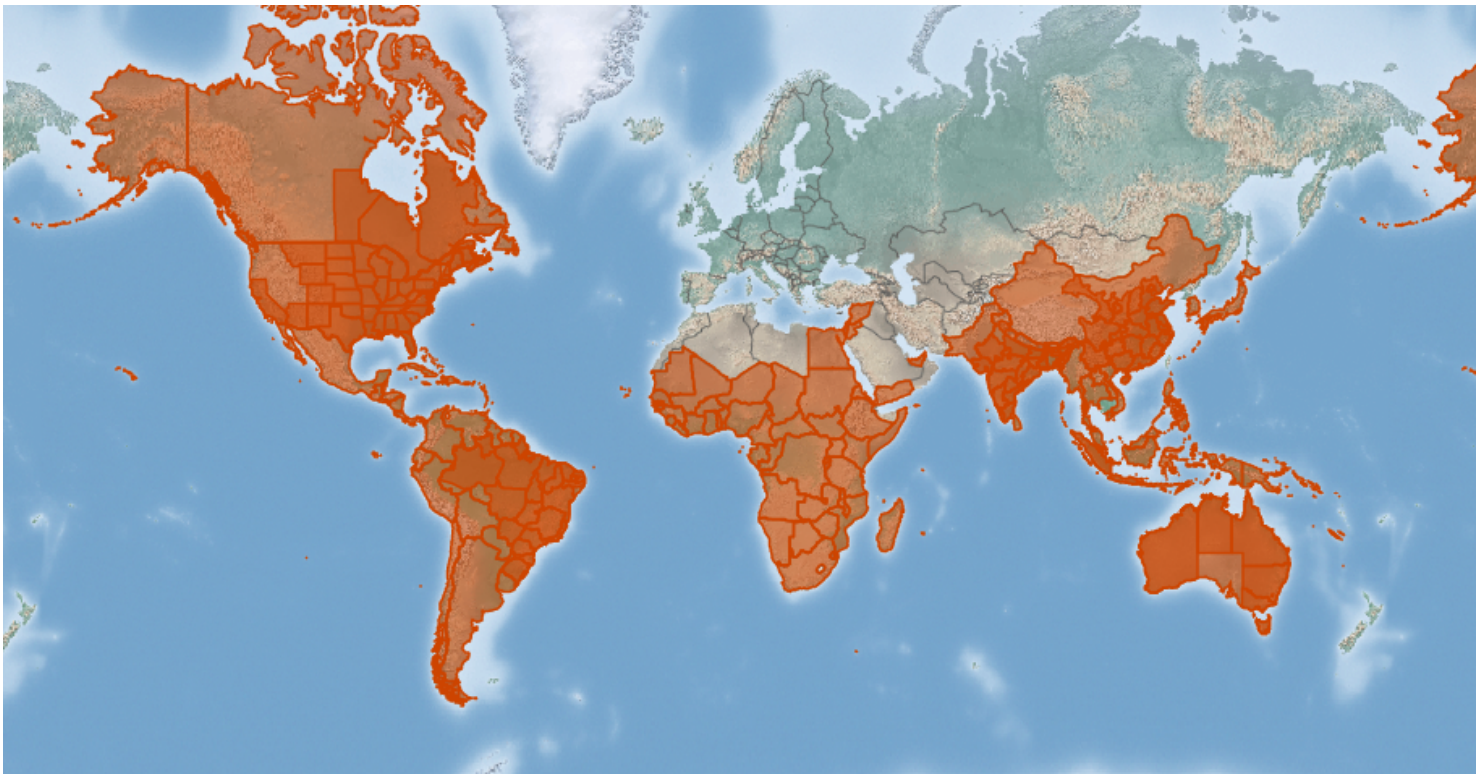

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