HarvestChoice
BETTER CHOICES, BETTER LIVES

PEST GEOGRAPHY

SEPTEMBER 2014

Busseola fusca

(African Stem Borer)

Kendall Hauptfleisch[1], Tania Yonow[2,3], Darren J. Kriticos[2,3], and Noboru Ota[4]

[1] School of Animal, Plant and Environmental Sciences, University of the Witwatersrand, South Africa
[2] HarvestChoice, InSTePP, University of Minnesota, St. Paul, MN, USA
[3] CSIRO, Biosecurity and Agriculture Flagships, Canberra, Australia
[4] CSIRO, Agriculture Flagship, Wembley, WA, Australia

Background Information

Common Names:
African Stem Borer

Scientific Name:
Busseola fusca

Taxonomy:
Kingdom: Animalia; Phylum: Arthropoda;
Class: Insecta; Order: Lepidoptera;
Family: Noctitudae

Crop Hosts:
Maize (*Zea mays*), sorghum (*Sorghum sp.*),
sugarcane (*Saccharum sp.)*

Introduction

Busseola fusca (Fuller), also known as the African stem borer, is a moth, indigenous to tropical Africa (Harris and Nwanze 1992). Although indigenous, it was first recognised as a pest of maize in South Africa, and has become economically important in many of the maize growing countries on the African continent (Haile and Hofsvang 2001; Kfir et al. 2002). *B. fusca* also co-exists with an alien invasive moth *Chilo partellus,* the spotted stem borer, particularly in the agro-ecological zones of Kenya (Abate et al. 2000). In some areas, such as the high elevations of the eastern Highveld region of South Africa, *B. fusca* has been reported to have been partially displaced by *C. partellus* (Kfir 1997).

Figure 1. Adult *Busseola fusca* moth (left) and *B. fusca* caterpillar (right). Photographs by D. Cugala and B. Le Ru, ICIPE.

Busseola fusca larvae feed on the aboveground parts of the grass hosts, causing economically important yield losses to crops such as maize. Feeding and tunnelling by *B. fusca* larvae can result in the destruction of the growing point (resulting in "deadhearts"), early leaf senescence, interference with nutrient and metabolite translocation resulting in malformation of the grain, stem breakage, plant stunting, and direct damage to ears (Unnithan 1987; Harris and Nwanze 1992; Kfir et al. 2002). Tunnels in the plant stem may also predispose hosts to infection. Yield loss estimates may vary with region, *B. fusca* infestation levels and plant developmental stage (van Rensburg and Flett 2008).

Known Distribution

Busseola fusca (Figure 1) is currently known to occur in most countries south of the Sahara, and has not yet been reported anywhere outside of Africa (Harris and Nwanze 1992; Haile and Hofsvang 2001) (Figure 2).

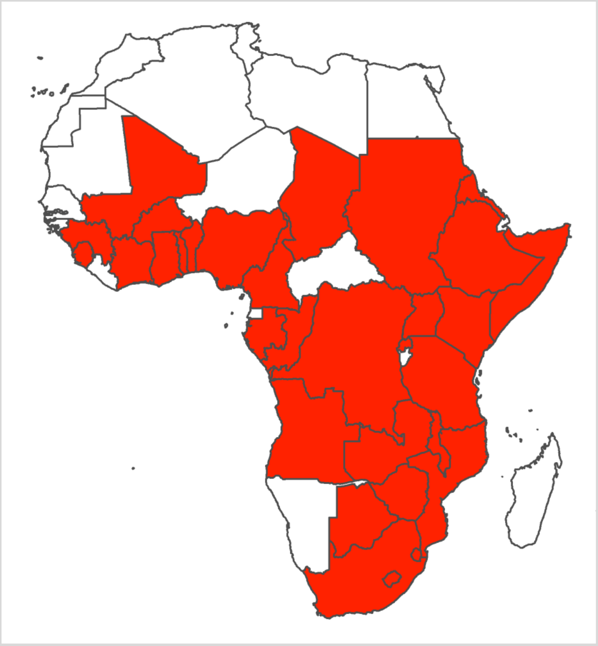

Figure 2. Reported African occurance of *Busseola fusca* by countries. Adapted from Harris and Nwanze (1992).

Suggested citation: Hauptfleisch, K., Yonow, T., Kriticos, D.J. , and Ota, N. (2014). *Busseola fusca*. HarvestChoice Pest Geography. St. Paul, MN: InSTePP-HarvestChoice.

Busseola fusca seems to display geographical differences in ecological preferences. In Eastern and southern Africa *B. fusca* is a pest at higher altitudes (>1,500 m), while in West Africa it occurs from sea level to above 2,000 m (Kfir et al. 2002). Haile and Hofsvang (2001) recorded *B. fusca* between 1,450 m and 2,350 m in Eritrea and in Cameroon (Central Africa) it is abundant from mid to high altitudes (700-1,000 m) (Ndemah et al. 2001 in Sezonlin et al. 2006). Others have reported that it is unable to tolerate the warm temperatures occurring below 2,000 ft (610 m) (Nye 1960 in Haile and Hofsvang 2001). The distribution of *B. fusca* seems to be further influenced by moisture gradients. In West Africa, *B. fusca* is recorded as a pest in the dry savannah zone in lower altitudes (Kfir et al. 2002), yet other studies record it being more abundant in the rainforest than the savannah (Moyal 1998 in Sezonlin et al. 2006). Three major population groups of *B. fusca* have been distinguished: a homogeneous and geographically isolated population from West Africa, and two populations from East and Central Africa with overlapping distributions (Sezonlin et al. 2006).

Despite it being a major pest in Africa, and despite the fact that it occurs in contrasting climatic zones, there is virtually no data published on the developmental biology of *B. fusca* in these different areas. It is impossible for a single species to complete 2-3 generations in the warmer West African countries [Burkino Faso (Nwanze 1988); southern Ghana (Bouadu et al. 2000; Hordzey and Botchey 2012); northern Nigeria (Harris 1962; Mcfarlane 1990)] and to also complete the same number of generations in the much cooler, higher altitude areas of Ethiopia (Gebre-Amlak 1989b; Yitaferu and Gebre-Amlak 1994) and Lesotho (Ebenebe et al. 2000). The annual heat sum in such different areas will clearly be very different. All the biological evidence supports the suggestion that there are different mitochondrial clades with overlapping distributions and different ecological characteristics (Sezonlin et al. 2006; Félix et al. 2009). With insufficient biological data available to distinguish the climatic preferences of each of these clades, this analysis has instead tried to capture the overall distribution of the *Busseola fusca* species complex.

Description and Biology

B. fusca exhibits complete metamorphosis, including egg, larval, pupal, and adult stages. *B. fusca* has 2-3 distinct generations in most locations (Harris and Nwanze 1992; Krüger 2007). However, in areas that are warm and humid, some *B. fusca* larvae may give rise to a fourth adult generation (Harris and Nwanze 1992). Another factor that plays a role in the biology of *B. fusca* is larval diapause. Much work has been conducted on the diapause strategies of *B. fusca*, and it appears that larvae diapause in most locations during cold, dry periods (Harris and Nwanze 1992). The state of host plant maturity is thought to be a critical factor in the induction of diapause (Usua 1973; Unnithan 1987), while soil moisture is imperative for its termination (Okuda 1988; Kfir et al. 2002; Gebre-Amlak 1989a). Temperature and photoperiod appear not to influence diapause (Usua 1973). It has been suggested that diapause in *B. fusca* is obligatory (Kfir 1991), but this is unconfirmed. Between 9 and 14 days after pupation, the adults emerge from emergence windows bored by the larvae prior to pupation (Harris and Nwanze 1992). Plants most attractive for oviposition are those that germinated 3-5 weeks prior to eclosion. Female *B. fusca* prefer the underside of the youngest fully unfolded leaf as oviposition sites (Harris and Nwanze 1992). Eggs generally hatch about a week later, while larvae take 3-5 weeks to develop. *Busseola fusca* eggs are hemispherical, with crenulations, and are laid in clusters (Harris and Nwanze 1992). Reports of total fecundity vary from 30-100 eggs (Harris and Nwanze 1992) to 723 eggs (Unnithan 1987). Upon hatching, larvae disperse and then enter the leaf whorls, boring into the stems, producing extensive tunnels in the stem and cob (Harris and Nwanze 1992). Larvae of *B. fusca* look similar to those of *C. partellus* in many ways. *Busseola fusca* larvae are 40 mm long when fully grown, normally a creamy white colour with a distinctive grey tinge. Sometimes *B. fusca* larvae have a pink colour similar to *C. partellus*. Both borers have a brown head capsule, but *B. fusca* can be distinguished from *C. partellus* by the hooks on the prolegs (Harris and Nwanze 1992). Hooks on the prolegs of *B. fusca* are arranged in a semicircle, while those in *C. partellus* are arranged in a full circle (Harris and Nwanze 1992).

Host Crops and Other Plants

The main crop hosts for *B. fusca* are maize (*Zea mays* L.) and sorghum (*Sorghum bicolour* L.) as well as pearl millet (*Pennisetum glaucum*), finger millet (*Eleusine coracana* L.), and sugarcane (*Saccharum officinarum*), but to a much lesser extent (Harris and Nwanze 1992; Gounou et al. 2009). Although the host plant on which *B. fusca* originally evolved is unknown, indigenous African grasses have been recorded as hosts, specifically *Sorghum verticilliflorum* (Steud.) Piper (including *Sorghum arundinaceum*), *Pennisetum purpureum* Schum., *Panicum maximum* Jacq., *Hyparrhenia rufa* Nees (Stapf), *Rottboellia exaltata* (L.), and *Phragmites* sp. (Harris and Nwanze 1992).

Potential Distribution

A CLIMEX model for *B. fusca* was developed using the "Wet Tropical" species template as a starting point. Where appropriate, parameter values were informed by knowledge of the species biology. The remaining parameters were then adjusted iteratively until the projected potential distribution (area where the Ecoclimatic Index > 0) was in accord with the known distribution of the three major population groups of *B. fusca*. The CliMond 1975H historical climate dataset was used throughout the modelling (Kriticos et al. 2012). The model parameters (Table 1) were fitted using a natural rainfall scenario. Subsequently, an irrigation scenario (2.5 mm day^{-1} applied as top-up) was run and the results compared with xeric areas where cropping is conducted under irrigated conditions. A composite climate suitability map was created by combining the natural rainfall and irrigation scenario results using the data from Siebert et al. (2005).

Table 1. CLIMEX Parameter Values for *Busseola fusca*

Parameter	Description	Value
Moisture		
SM0	lower soil moisture threshold	0.1
SM1	lower optimum soil moisture	0.4
SM2	upper optimum soil moisture	1.5
SM3	upper soil moisture threshold	2.5
Temperature		
DV0	lower threshold	20 °C
DV1	lower optimum temperature	25 °C
DV2	upper optimum temperature	29 °C
DV3	upper threshold	32 °C
Cold Stress		
TTCS	cold stress temperature threshold	1°C
THCS	temperature threshold stress accumulation rate	-0.002 week^{-1}
Heat Stress		
TTHS	heat stress temperature threshold	35 °C
THHS	temperature threshold stress accumulation rate	0.001 week^{-1}
Dry Stress		
SMDS	soil moisture dry stress threshold	0.1
HDS	stress accumulation rate	-0.03 week^{-1}
Irrigation Scenario		
	2.5 mm day^{-1} as top-up throughout the year	

The resulting climate suitability maps are based on known and inferred relationships between population growth and temperature, soil moisture, heat, cold, and drought (Smithers 1960; Usua 1968, 1973; Unnithan 1987; Mcfarlane 1990; Harris and Nwanze 1992; Chabi-Olaye et al. 2001; Dixon et al. 2009; You et al. 2009).

Soil moisture parameters were set to biologically reasonable values. The soil moisture limit for growth was set to approximate permanent wilting point (Kriticos et al. 2003). The upper limit for optimal growth (SM2) was set to 1.5, acknowledging that *B. fusca* can tolerate conditions with minor water-logging. The lower limit for optimal growth (SM1) was adjusted to provide appropriate suitability in marginally dry areas.

The lower temperature threshold for growth was set to 20 °C, which is somewhat lower than the 23 °C indicated by Usua (1968, 1973), but enables persistence in cooler, high altitude regions in which this species has been recorded. The lower temperature for optimal growth was set to 25 °C. This is marginally lower than the 27 °C indicated by Usua (1968) and Harris and Nwanze (1992), but is in line with values used for mass rearing techniques (Ratnadass et al. 2001; Félix et al. 2009). The upper optimal temperature for growth was set to 29 °C (Usua 1968; Harris and Nwanze 1992), and the maximum temperature was set at 32 °C in accord with observations by Usua (1968) and Dixon et al. (2009).

Larvae diapause in most locations during cold, dry periods (Smithers 1960; Usua 1968; Harris and Nwanze 1992; Ebenebe et al. 2000). The state of host plant maturity may be a critical factor in the induction of diapause (Usua 1973; Unnithan 1987), and soil moisture is imperative for its termination (Okuda 1988; Kfir et al. 2002; Gebre-Amlak 1989a). However, as diapause in CLIMEX is operated by day length and temperature parameters, it cannot be used for this species.

Although temperatures below 23 °C cause high levels of mortality (Usua 1973), *B. fusca* has a diapause mechanism to enable it to overwinter (Smithers 1960; Usua 1968; Ebenebe et al. 2000). Overall, Cold Stress is therefore probably not a limiting factor in Africa. A temperature threshold model of Cold Stress was used, with a 1 °C threshold and a stress accumulation rate of -0.002. With these settings, the only areas that experience any Cold Stress are the very high altitude regions of Lesotho, South Africa, Morocco, and Algeria.

Heat Stress parameters were set to allow persistence in all of the countries from which it has been observed. The threshold of 35 °C is marginally higher than the lethal temperature of 32 °C (Usua 1968).

Dry Stress was fitted by using the lower soil moisture growth threshold and adjusting the rate to limit the distribution to localities noted by Nwanze (1988) in southern Burkina Faso. Wet Stress was not used.

The threshold annual heat sum required for population persistence (PDD) was not used, as it was not possible to use PDD to predict the correct number of generations in all the climatic zones where *B. fusca* occurs. This is likely due to genotype specific base temperatures for development, and possibly also the heat sum required to complete a generation. It may also be complicated by diapause periods, which were not simulated here.

The Ecoclimatic Index (EI) for *B. fusca* is shown for Africa in Figure 3. The potential distribution of *B. fusca* matches the available distribution data for this complex (Harris and Nwanze 1992; Sezonlin et al. 2006). The EI values are the greatest in the wetter tropical parts of Africa: e.g., Cameroon, Equatorial Guinea, Gabon, the Congo, and the Democratic Republic of the Congo.

The distribution was compared against the known distribution of maize and sorghum in Africa (You et al. 2012). The modelled distribution of *B. fusca* shows a good overlap with the two crop species in Africa.

The potential of *B. fusca* as a pest in other sorghum and maize growing countries was assessed by mapping the potential distribution across the globe, including both irrigated and non-irrigated areas (Figure 4). This indicated that the African stem borer, if introduced, may establish and become a pest in most of the maize growing regions globally. According to the model it might do especially well along the east coast of Brazil, Madagascar, and in Indonesia and Thailand.

The CLIMEX model presented here was fitted to extremely coarse distribution information, and encompasses three different clades with overlapping geographical distributions (Figure 5; Sezonlin et al. 2006; Félix et al. 2009). Hence, the stress functions and potential range limits of the species complex should be interpreted as being broadly indicative only. If, in the future, the range boundary conditions need refinement, relatively cheap and simple pheromone surveys could be laid out along each of the hot, dry, wet, and cold boundaries as indicated by the present model (Kriticos et al. 2007). Better data on the biology of *B. fusca* in the different regions where the various clades occur would assist in modelling the climate requirements of each of these clades separately. The growth potential of *B. fusca* within its range limits may be over-represented in some areas by the EI values due to the fact that diapause was not simulated. The effect of this is likely to be slight however, because it will affect growth potential only in periods of drought or cold, during which no growth is occurring in the model. *Busseola fusca* could potentially extend its range in warm, dry regions if irrigation is practiced.

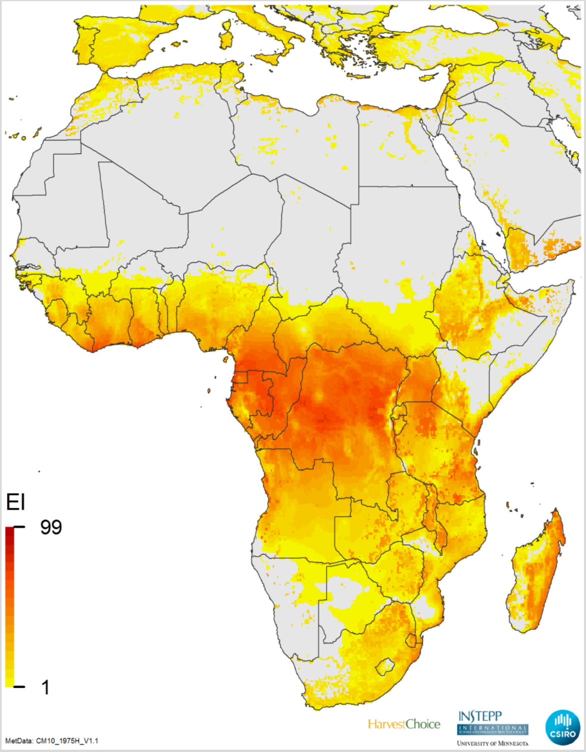

Figure 3. Modelled climate suitability of Africa for *Busseola fusca* as a composite of natural rainfall and irrigation based on the irrigation areas identified in Siebert et al. (2005).

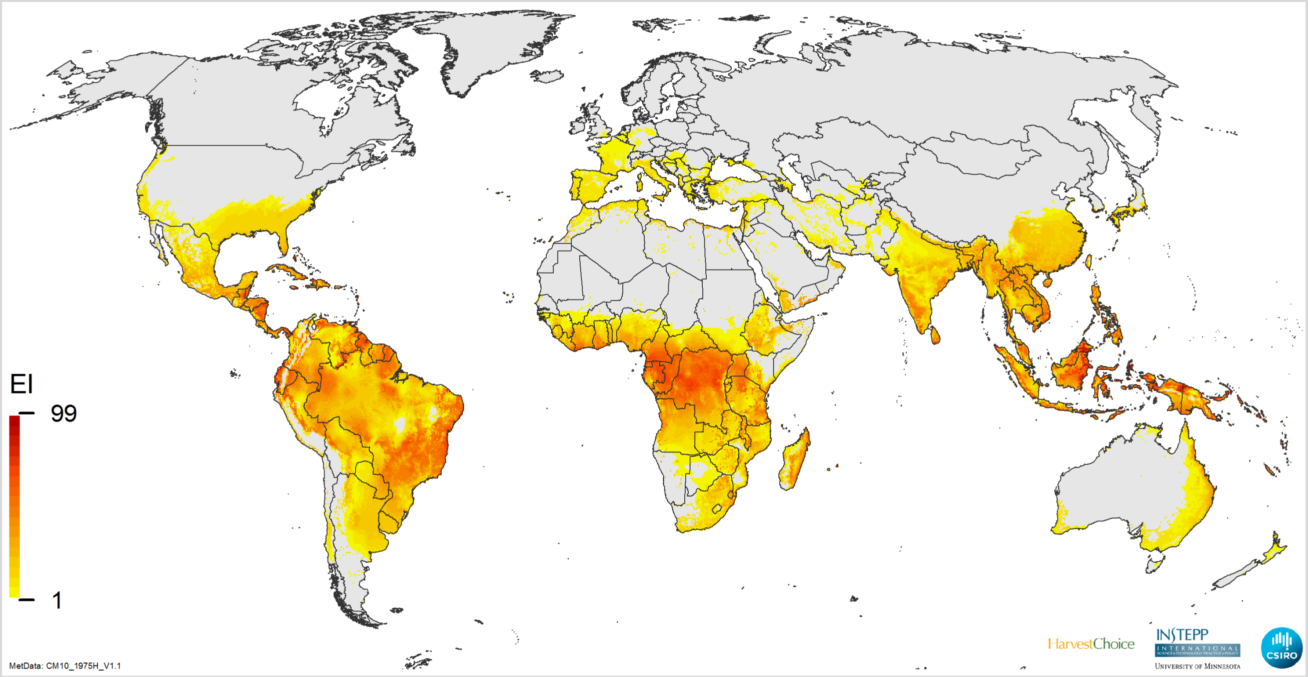

Figure 4. Modelled global climate suitability for *Busseola fusca* as a composite of natural rainfall and irrigation based on the irrigation areas identified in Siebert et al. (2005).

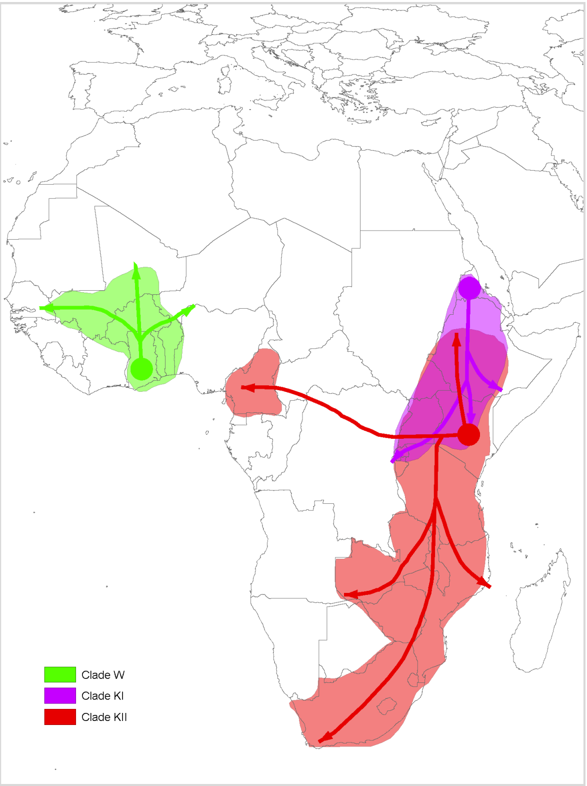

Figure 5. Overlapping geographical distributions of three different clades of Busseola *fusca* (adapted from Sezonlin et al. 2006).

References

Abate, T., van Huis, A., and Ampofo, J.K.O. (2000). Pest management strategies in traditional agriculture: An African perspective. *Annual Review of Entomology* 45: 631-659.

Buadu, E.J., Gounou, S., Cardwell, K.F., Mochiah, B., Botchey, M., Darkwa, E., and Schulthess, F. (2002). Distribution and relative importance of insect pests and diseases of maize in southern Ghana. *African Plant Protection* 8: 3-11.

Chabi-Olaye, A., Schulthess, F., Poehling, H.M., and Borgemeister, C. (2001). Factors affecting the biology of *Telenomus isis* (Polaszek) (Hymenoptera: Scelionidae), an egg parasitoid of cereal stem borers in West Africa. *Biological Control* 21: 44-54.

Dixon, A.F.G., Honek, A., Keil, P., Kotela, M.A.A., Sizling, A.L., and Jorosik, V. (2009). Relationship between the minimum and maximum temperature thresholds for development in insects. *Functional Ecology* 23: 257-264.

Ebenebe, A.A., van den Berg, J., and van der Linde, T.C. de K. (2000). Seasonal flight activity of the maize stalk borer, *Busseola fusca* (Fuller) (Lepidoptera: Noctuidae), in Lesotho. *African Entomology* 8(1): 63-68.

Félix, A.-E., Genestier, G., Malosse, C., Calatayud, P.-A., Le Rü, B., Silvain, J.-F., and Frérot, B. (2009). Variability in pheromone communication among different haplotype populations of *Busseola fusca. Journal of Chemical Ecology* 35: 618–623.

Gebre-Amlak, A. (1989a). Termination of diapause in the maize stalk borer, *Busseola fusca* (Fuller) (Lep., Noctuidae), in Awassa, southern Ethiopia. *Journal of Applied Entomology* 107: 160-165.

Gebre-Amlak, A. (1989b). Phenology and fecundity of maize stalk borer *Busseola fusca* (Fuller) in Awassa, Southern Ethiopia. *Insect Science and its Application* 10(2): 131-137.

Gounou, S., Jiang, N., and Schulthess, F. (2009). Long-term seasonal fluctuations of lepidopteran cereal stemborers and their natural enemies on maize and wild host plants in southern Benin. *Insect Science* 16(4): 329-341.

Haile, A. and Hofsvang, T. (2001). Survey of the lepidopterous stem borer pests of sorghum, maize and pearl millet in Eritrea. *Crop Protection* 20(2): 151-157.

Harris, K.M. (1962). Lepidopterous stem borers of cereals in Nigeria. *Bulletin of Entomological Research* 53: 139-171.

Harris, K.M. and Nwanze, K.F. (1992). *Busseola fusca* (Fuller), the African maize stem borer: a handbook of information. *Information Bulletin* 33. ICRISAT. Oxon, UK: CABI. 92 pp.

Hordzi, W.H.K. and Botchey, M.A. (2012). Some parasitoids of lepidopterous stem borer pests on maize in southern Ghana. *Bulletin of Environment, Pharmacology and Life Sciences* 1(6): 77–83.

Kfir, R. (1991). Duration of diapause in the stem borers, *Busseola fusca* and *Chilo partellus. Entomologia Experimentalis et Applicata* 61: 265-270.

Kfir, R. (1997). Competitive Displacement of *Busseola fusca* (Lepidoptera: Noctuidae) by *Chilo partellus* (Lepidoptera: Pyralidae). *Annals of the Entomological Society of America* 90(5): 619-624.

Kfir, R., Overholt, W.A., Khan, Z.R., and Polaszek, A. (2002). Biology and management of economically important lepidopteran cereal stem borers in Africa. *Annual review of Entomology* 47: 701-731.

Kriticos, D.J., Sutherst, R.W., Brown, J.R., Adkins, S.A., and Maywald, G.F. (2003). Climate change and biotic invasions: a case history of a tropical woody vine. *Biological Invasions* 5: 145-165.

Kriticos, D.J., Potter, K.J., Alexander, N., Gibb, A.R., and Suckling, D.M. (2007). Using a pheromone lure survey to establish the native and potential distribution of an invasive lepidopteran, *Uraba lugens. Journal of Applied Ecology* 44: 853-863.

Kriticos, D.J., Webber, B.L., Leriche, A., Ota, N., Macadam, I., Bathols, J., and Scott, J.K. (2012). CliMond: global high resolution historical and future scenario climate surfaces for bioclimatic modelling. *Methods in Ecology and Evolution* 3: 53-64.

Krüger, W. (2007). Ecology of maize stemborers in irrigated subsistence farming systems in the Limpopo Province. MSc Thesis, North-West University, Potchefstroom, South Africa.

Mcfarlane, J.H. (1990). Damage assessment and yield losses in sorghum due to the stem borer *Busseola fusca* (Fuller) (Lepidoptera: Noctuidae) in Northern Nigeria. *Tropical Pest Management* 36(2): 131-137.

Moyal, P. (1998). Infestation patterns and parasitism of the maize stalk borer, *Busseola fusca* (Fuller) (Lepidoptera: Noctuidae) in the Ivory Coast. *African Entomology* 6: 289–296.

Ndemah, R., Schulthess, F., Korie, S., Borgemeister, C., and Cardwell, K.F. (2001). Distribution, relative importance and effect of lepidopterous borers on maize yields in forest zone and mid-altitude of Cameroon. *Journal of Economic Entomology* 94: 1434 –1444.

Nwanze, K.F. (1988). Distribution and seasonal incidence of some major insect pests of sorghum in Burkina Faso. *Insect Science and its Application* 9(3): 313-321.

Nye, I.W.B. (1960). The insect pests of graminaceous crops in East Africa. *Colonial Research Study* 31. 48 pp. London: H.M.S.O.

Okuda, T. (1988). Effect of artificial wetting and rainfall on the larval diapause of a stem borer, *Busseola fusca* in Western Kenya. *Entomologia Experimentalis et Applicata* 48(3): 263-267.

Ratnadass, A., Traoré, T., Sylla, M., and Diarra, D. (2001). Improved techniques for mass-rearing *Busseola fusca* (Lepidoptera: Noctuidae) on an artificial diet. *African Entomology* 9(2): 167-175.

Sezonlin, M., Dupas, S., Le Rü, B., Le Gall, P., Moyal, P., Calatayud, P.-A., Giffard, I., Faure, N., and Silvain, J.-F. (2006). Phylogeography and population genetics of the maize stalk borer *Busseola fusca* (Lepidoptera, Noctuidae) in sub-Saharan Africa. *Molecular Ecology* 15(2): 407-420.

Siebert, S., Doll, P., Hoogeveen, J., Faures, J.M., Frenken, K., and Feick, S. (2005). Development and validation of the global map of irrigation areas. *Hydrology and Earth System Sciences* 9: 535-547.

Sithole, S.Z. (1989). Sorghum stem borers in southern Africa. International Workshop on Sorghum Stem Borers, 17-20 November 1987, ICRISAT Centre, India. Pantacheru, A.P. 502 324, India pp 41-47.

Smithers, C.N. (1960). Some recent Observations on *Busseola fusca* (Fuller) (Lep., Noctuidae) in Southern Rhodesia. *Bulletin of Entomological Research* 50(4): 809-819.

Unnithan, G.C. (1987). Development and reproductive biology of the maize stem-borer *Busseola fusca* Fuller (Lepid., Noctuidae). *Journal of Applied Entomology* 104: 172-179.

Usua, E.J. (1968). Temperature and relative humidity effects on the development of the immature stages of the maize stem borers *Busseola fusca* and *Sesamia calamistis*. *Journal of Economic Entomology* 61(4): 1091-1093.

Usua, E.J. (1973). Induction of diapause in the maize stemborer, *Busseola fusca*. *Entomological Experimentalis et Applicata* 16: 322-328.

van Rensburg, J.B.J. and Flett, B.C. (2008). A review of research achievements on maize stem borer, *Busseola fusca* (Fuller) and Diplodia ear rot caused by *Stenocarpella maydis* (Berk. Sutton). *South African Journal of Plant and Soil* 27(1): 74-80.

Yitaferu, K. and Gebre-Amlak, A. (1994). Phenology and survival of the maize stalk borer, *Busseola fusca* in eastern Ethiopia. *Insect Science and its Application* 15 (2): 177-184.

You, L., Crespo, S., Guo, Z., Koo, J., Sebastian, K., Tenorio, M.T., Wood, S., and Wood-Sichra, U. (2012). Spatial Production Allocation Model (SPAM) 2000 Version 3 Release 6 (http://harvestchoice.org/products/maps).

ACKNOWLEDGEMENTS

HarvestChoice would like to acknowledge Noboru Ota for spatial data analysis and the production of all maps. This brief was prepared with support from the Bill and Melinda Gates Foundation by way of the HarvestChoice project with additional support from the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and The International Science and Technology Practice and Policy Center (InSTePP), University of Minnesota.

ABOUT HARVESTCHOICE

HarvestChoice generates knowledge products to help guide strategic investments to improve the well-being of poor people in sub-Saharan Africa through more productive and profitable farming. Learn more at www.harvestchoice.org.