

## Insect pest fauna of soybean: A review of Major insect pest identification, diversity, Meteorological factor, and Biocontrol agents

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### Abstract

Soybean (*Glycine max*) is a globally important crop, essential for food, feed, and biofuel production. However, its productivity is significantly threatened by a diverse range of insect pests. These pests including mainly griddle beetle, aphids, white fly, stink bug, bean leaf beetle, *Spodoptera litura* and soybean pod borers these cause economic losses by directly feeding on plant tissues, transmitting diseases, or affecting seed quality and yield. This review provides a comprehensive overview of soybean insect pests, including their diversity, identification, life cycle and ecology, with a focus on their impact across different soybean-growing regions. The dynamics of pest outbreaks are examined in the context of environmental factor like temperature humidity and soil. In addition to its integrated pest management approaches, encompassing biological control agents also included. Biocontrol agents are used to reduce insect pests of soybean.

**Keywords:** Soybean, Insect pest, Identification, Biocontrol agent, Integrated pest management.

### Introduction

Soybean (*Glycine max* L. Merrill) is the most important leguminous crop which is native to east Asia. It is widely cultivated to for its edible seeds, which are rich source of protein and other nutrients are also present. The cultivation and use of soybean beginning in China in 3000 years ago, where they were considered, it is a sacred crop Krishnamurthy, Shivashankar, (1975) [30]. To the citizens of Japan, China, Manchuria, Korea, Philippines, and Indonesia, for centuries, soybean has meant to be grain, bread and oil.

This may be attributed to the reason, why in these countries, it has earned epithets like “Cow of the field” or “Gold from soil” (Horvath, 1926) [23]. Diversity of soybean was more established in the West. China produced about 80 % of the world’s soybean in 1921 (Bisaliah 1988) [6]. Soybean was introduced from China in tenth century AD through the Himalayan routes, and also brought in via Burma (now Myanmar) by traders from Indonesia in our country.

Most Lepidoptera are primarily defoliators, such as the soybean looper, *Chrysodeixis includens* (Walker), and velvet bean caterpillar, *Anticarsia gemmatilis* (Hübner). Although these defoliators occur frequently in soybeans, management action is not always warranted, as soybeans generally tolerate low levels of defoliation (Haile *et al.*, 1998) [23]

*Helicoverpa armigera* (Hubner) is a major pest of soybean (Naseri *et al.*, 2009) [35] with many crops attacking more than 60 plant species belonging to more than 47 families (like as soybean, sorghum, maize, cotton, groundnuts, cowpea, tomato and green pepper sunflower).

In this review analysis, various aspects of soybean insect pest fauna are included such as: 1. Identification of insect pest of soybean; 2. Nature of damage of insect pest of soybean; 3. Life cycle of major Insect pest of soybean 4. Meteorological effects on insect pest of soybean; 5. Biological control of insect pest of soybean; 6. Effect of

insect pest fauna on yield production of soybean has been included in this review study.

### Identification of insect pest

Insects’ pests can be identified by their color, shape, and other features. Traditionally to identify insect-pest different morphological traits are used. (Jinbo *et al.*, 2011) [27]. Identifications which are based on shape and structure are mostly challenging and consume more time. (Barrett and Hebert, 2005). With the help of routine taxonomy immature life stage like juveniles, early instar and pupae are not identified so most of the morpho taxonomic keys are used for the analysis of adults only (Barrett & Hebert, 2005). Adaptive flexibility often complicates the process of identifying and classifying living organisms. (Murugan *et al.*, 2016). Undescribed species are also challenging to identify on the basis of shape and outer structure. Moreover, high level of experience is requisite for the better use of morphological keys (Ball and Armstrong, 2006).

Garg *et al.*, (2014) [17] reported infestation of Girdle beetle on kharif season crop particularly they done their work on black gram, cowpea, Cluster bean, pigeon pea, Indian bean and soybean, investigation indicated that no incidence was observed on black gram, whereas maximum incidence and stem boring were recorded in soybean. Kushram, (2016) [32] identified *O. brevis*, *S. litura*, *C. acuta*, *B. tabaci*, *E. kerri* and Thrips *tabaci* were cause the severe damage in soybean crop. Along with this they also reported some other species of insect-pest of soybean. Das, (1998) [15] recorded two most serious insect-pest of soybean which is hairy caterpillar and stem fly by these species mostly defoliation of leaves occurred and Biswas, (2008) [5, 8] investigate in Gazipur and recorded almost 35 most important species of insect-pest of soybean. Biswas *et al.*, (2001) reported two major defoliator species of insect-pest of soybean which is leaf roller (*L. indicata*) and hairy caterpillar (*S. obliqua*) by these two-insect pest damage occurs to leaves about 60-80 percent.

## Some insects-pest of soybean



Stem fly



Gridle Beetle



Tobacco Caterpillar



Green Stink bug

Kaul and Das, (1986) investigate in Bangladesh on insect-pest of soybean crop, they found 14 species of insect pest damaging to soybean, among these, hairy caterpillar, cutworm, leaf roller (*L. indicata* F.) and bug (*N. viridula* L.) were recorded as major pests. Also they recorded that larva of Spodoptera species was present in maximum number this can lead to severe yield loss in soybean crop due to their polyphagous nature. In reproductive stage of soybean *Spodoptera litura* (F.) and *S. exigua* (Hübner) (Lepidoptera: Noctuidae) are the two important defoliators. Larvae can cause severe damage to the leaves and devastating them due to their highly polyphagous nature in the reproductive stage in soybeans (Chattopadhyay *et al.*, 2019) <sup>[11]</sup>.

### Nature of damage of insect pest of soybean

Insect pests can damage soybean by destroying leaves, pods, or stem. This damage can affect the plants' ability to photosynthesize. The tobacco cutworm (Lepidoptera: Noctuidae) is highly polyphagous. Girdle beetle, (*Obereopsis brevis*) as a leading stem borer, it causes most of damage to the stem of soybean plant, it has been recorded that species of adult Gridle beetle can cause holes in petiole and maximize harvest reduction (Chaudhary *et al.*, 2014) <sup>[10]</sup>.

G.C Biswas, (2001) observed the feeding nature of larva of *S. obliqua*, investigation revealed that first and second instar of larva occurred in maximum numbers and cause the leaves defoliation. After that third instar of the larva dispersed from the leaves of one plant to next plant. and leads the damage of leaves, shoot and flowers. RS Chouhan *et al.*, (2019) <sup>[12]</sup> reported that the maggot of stem fly caused serious damage to the plants and it entered the stem through the leaf petiole and damage the stem tunneling. Plants which are affected from stem tunneling shows the reddish color. Stink bug attack is mainly occurred in soybean pod-filling period Duncan and Walker, 1968 <sup>[14]</sup>; Panizzi *et al.*, 1979; Brier and Rogers, (1991) and these stink bug affect Soybean seed and lowers the quality of seeds. Beatriz S. Correa-Ferreira, Joacir de Azevedo (2002) <sup>[4]</sup> Grasshoppers affect both leaves and stem but prefer more digestible and nutritious leaves, as long as sufficient leaf tissue remained (as in oats and barley). Less densities of grasshoppers do not lead to the stem damage, so stems are less affected by grasshoppers. (Sultan *et al.*, 2003). In soybean, defoliation up to 33% has been recorded to be tolerated with less impact on crop, although this depends on interactions with other

environmental factors (such as soil moisture and soil fertility) (Pedigo *et al.*, 1986 <sup>[37]</sup>; Haile *et al.*, 1998) <sup>[23]</sup> The bean leaf beetle larva prefers stage feeding on the root system, and after a few weeks the larva grown in adults leads to feed on collective leaves of soybean crop. (Ronald *et al.*, 2014)

### Life cycle of major Insect pest of soybean

The *S. litural* has a complete life cycle containing four stages viz., egg, larva, pupa and adult. It undergoes six larval instars, pre-pupa and pupal stages before attaining the adult stage. The larva passed through six instars. The key character to identify *S. litural* is adults were medium sized moth, with dark colored forewings and light-colored hind wings. (Solanki *et al.* 2022,) <sup>[43]</sup>. The eggs are deposits by female moth on the underneath of soybean foliage. (producing around 600 eggs) development of eggs will take around 3 days in these three days eggs hatch and after that 6 larval stage occur. Complete development of eggs into adult will take time-period of four weeks. (soybean research and information network). Soybean aphids produced two wingless generations followed by a winged generation in early spring. (soybean research and information network).

### Meteorological effects on insect-pest of soybean

Meteorological factors (temperature, humidity, soil) play a significant role in the ecology and management of insect pests of soybean Brahman *et al.*, (2018) <sup>[2]</sup> and Jat *et al.*, (2017) <sup>[28]</sup> reported correlation of temperature with insect-pest species, they recorded that less temperature exhibited high population of larva of *H. armigera* this shows positive correlation.

Gadhiya *et al.*, (2014) <sup>[18]</sup> recorded effect of temperature on insect-pest of soybean, they revealed that larval population of *H. armigera* shows positive correlation at maximum, minimum and mean temperature.

Kumar, (2014) showed that tomato fruit borer larval population increase at minimum temperature and evaporation. Kujur, 2011 <sup>[31]</sup> reported peak activity of insect-pest population during the month of august and September. They recorded peak activity of Gridle beetle species in the month of September and highest activity of *S. litura* and *C. acuta* in the month of august.

Punithavalli *et al.*, (2013) <sup>[39]</sup> recorded highest activity of *Spodoptera litura* in the month of September. They found that optimum temperature and humidity will leads the

maximum numbers of eggs and larva. Sonkamble and Rana (2019) recorded that the larval population of *Spodoptera litura* increase during the month of September and then decreases gradually. Suyal *et al.*, (2018) <sup>[41]</sup> observed that population of *Spodoptera litura* and *Spilosoma obliqua* present in highest number during the month of August and first week of September. They revealed that meteorological factors like temperature and humidity shows correlation with the population of these larval species. (Wardle *et al.*, 2004) <sup>[46]</sup>. Gridle beetle positively correlated with relative humidity and with maximum temperature population of Gridle beetle decreases. (Patel *et al.*, 2019) <sup>[38]</sup>.

### Bio-control agent of insect pest of soybean

Integrated Pest Management (IPM) is a holistic approach to control pests and diseases in soybean production. IPM involves using a combination of techniques like crop rotation, chemical control and most important bio-control agents. Peshin *et al.*, (2009); Way & van Emden, 2000, Emden & Peakall, (1996) stated that in IPM method biocontrol agents done the great job at lower cost they revealed that biocontrol agents can significantly reduce the pest population naturally. (Bateman, 2003), which includes predatory insects, bird, parasitoids, and pathogens. Biocontrol agents are living organism or their by-products that are used to control pests and diseases. Biocontrol agents also refer as natural enemies, these agents done great job in the agroecosystem of various crop. These agents reduce insects-pest population and increase yield production. (Miguel A. Altieri *et al.*, 2024).

For the management of stink bugs augmentative biological control (ABC) is one of the effective method. for building a more stable soybean crop ecosystem, introduce *Telenomus podisi*, this can reduce the population of stink bugs. (Adeney de F. Bueno *et al.*, 2024). The victory of biological control shows the natural enemies, hosts and their prey. (Robert F. Luck 1990) <sup>[33]</sup>. Biological control method includes predatory insects, parasitoids and breeding of natural enemies. Birds play a vital role in controlling insect pest populations in agriculture, horticulture, forestry, and our environment. (Halder and Seni, 2021) <sup>[19, 20]</sup>. Birds can be effective and crucial in managing insect-pest population, insectivorous birds can consume around 400–500 million tonnes of insect prey each year, according to Nyffeler *et al.*, (2018) <sup>[36]</sup> with nearly 28 million tonnes (7 per cent of total) coming from agricultural areas. Uses of birds as biocontrol agents can lead to lower use of pesticides improve water quality, save time, provide valuable habitats. (Halder *et al.*, 2021) <sup>[19, 20]</sup>. Integrated Pest Management (IPM) concepts are now popular in farmers and this can lead to manage the insect-pest population naturally. Insectivorous birds feed on variety of insect-pests. Weevils are eaten by the Indian tree pie (*Dendrocitta vagabunda*), whereas aphids and other soft-bodied insects are eaten by the Large-pied wagtail (*Motacilla maderaspatensis*) and the Tailor bird (*Orthotomus sutorius*) (Verghese and Sriharan, 1993).

### Effect of Insect Pest Fauna on yield Production of Soybean Crop

Insect pests can significantly impact soybean yield production. Effect of these insect-pest on the yield of soybean crop recorded worldwide. (Wrather *et al.*, 2001) <sup>[47]</sup> recorded that in 2006 in the southern region of United States, disease losses occurs severely (Koening, 2007) <sup>[29]</sup>.

Insect-pest damage mostly shoot apical system (includes leaves. Flowers, stem) and root system. (Higley, 1994) <sup>[22]</sup> and this cause severe damage to the yield and lowers the quality of seeds. Mostly this type of damage caused by pod or seed feeders, which include various stink bugs, corn earworm, bean leaf beetle, grasshoppers, several armyworms, and sometimes high population densities of soybean looper and velvet bean caterpillar (Steffey *et al.*, 1994; Turnipseed, 1976; Hammond *et al.*, 1991 <sup>[21]</sup>; Zeiss and Klubertanz., 1994) <sup>[49]</sup> during early to mid-reproductive stage pod feeding insects can leads to yield loss and downs the seed quality. (Smith & Bass, 1972) <sup>[42]</sup>. When insect pest infection occurs during vegetative and reproductive growth period content of Linoleic and linolenic acids decrease in soybean crop (Todd *et al.*, 1973) <sup>[45]</sup>. Damage caused by stink bug population can leads to discolor the seed and lowers the quality of seeds. (Miner, 1966) <sup>[34]</sup>. Storage form of soybean is susceptible to many insect-pest population like Bean leaf beetle and many species of Grasshoppers (Hammond, 1996 <sup>[21]</sup>; Smelser & Pedigo, 1992; Turnipseed, 1976). Two insect-pest species of soybean aphid, *Aphis glycines*, reported as serious insect-pest because of its population density and it can convey a wide spectrum of plant disease. (Wu *et al.*, 2004) <sup>[48]</sup>.

Discovery of soybean aphids firstly reported in Minnesota in 2006 and now it continuously extended in the region of U.S (Ragesdale *et al.*, 2004) <sup>[40]</sup>

### Conclusion

Soybean [*Glycine max (L.) Merrill*] has high range of nutrients and provides a spectrum of protein, essential vitamins, minerals and micronutrients. Soybeans are rich in protein and it has content of 28-30 grams protein per 100 grams along with protein content soybean is also rich in fat mostly in unsaturated fats. Soybean also contain high amount of carbs (almost 30-45 gram per 100 grams), fibers and other micronutrients like vitamin k, folate, manganese, copper, phosphorus. Soybean is a major crop of kharif season but it also grown in rabi. It majorly grown in Madhya Pradesh, Maharashtra, Rajasthan, Chhattisgarh, Andhra Pradesh and Karnataka. Soybean crop is prone to many pests attack but it majorly attacked by insect pest like defoliators, gridle beetle, tobacco caterpillar, green semilooper, aphids, stem fly, grasshopper, stink bug, jassids, etc. Infestation of these pest affect yield of soybean production significantly and also lower the quality of seed grains. Abiotic factors like (temperature, humidity, soil, rainfall) also play crucial role in life cycle of insect pest fauna. For example, Gridle beetle shows negative correlation with high temperature and positive correlation with high humidity and white fly shows maximum population density with water shortage. To manage the insect pest population integrated pest management is an excellent approach it includes variety of methods one of them a traditional natural method is biocontrol agents like predatory insects, birds, viruses, fungi, bacteria and many more. These agents can control insect pest population, disease management, improve soil health, improve crop quality and maximize yield production.

### References

1. Alteri AM, Nicholls IC, Dinelli G. Towards an agroecological approach to crop health: reducing pest incidence through synergies between plant diversity and

- soil microbial ecology. Sustainable Agriculture,2024;2:6.
2. Brahman SK, Awasthi AK, Singh S. Studies on insect pests of soybean (*Glycine max*) with special reference to seasonal incidence of *Lepidopteran* defoliators. J Pharmaco Phyto chem,2018;7(1):1808-1811.
  3. Biswas GC. Insect pests of soybean (*Glycine max* L.), their nature of damage and succession with the crop stages. Journal of the Asiatic Society of Bangladesh, Science,2013;39(1):1-8.
  4. Correa-Ferrira BS, De Azevedo J. Biology of leaf-eating caterpillar, *Spodoptera litura* (Fab.) infesting soybean. Agricultural and Forest Entomology, 2002.
  5. Biswas GC. Insect pests and their management of soybean crop in Bangladesh. Proceedings of the Workshop on Prospects and Performance of Soybean in Bangladesh, 2008, 67. (M.A. Bakr ed.) ORC, BARI, Gazipur.
  6. Bisalial S. Soybean development in India. CGPRT, 1988, 5.
  7. Ball SL, Armstrong KF. DNA barcodes for insect pest identification: a test case with tussock moths (*Lepidoptera: Lymantriidae*). Can J Forest Res,2006;36:337-350.
  8. Biswas GC, Hossain MM, Mazumder UK. Screening of some soybean lines against soybean leaf roller. Bangladesh J Agril Res,2001;26(2):295-300.
  9. Beuno FA, Sutil PW, Jankhe MS, Carvalho AG, Cingolani FM, Colmenarez CY, Corniani N. Biological control as part of the soybean integrated pest management (IPM): potential and challenges. Agronomy,2023;13(10):2532.
  10. Chaudhary HR, Patidar BK, Meena DS, Dashora A. Assessment of yield losses due to a major insect pest in soybean. ABSTRACT Proceeding of Soycon-2014 International Soybean Research Conference on "Mitigating productivity constraints in soybean for sustainable agriculture",2014, 245.
  11. Chattopadhyay N, Balasubramaniam R, Attri SD, Ray K, John G, Khedikar S, Karmakar C. Forewarning of incidence of *Spodoptera litura* (Tobacco caterpillar) in soybean and cotton using statistical and synoptic approach. Journal of Agrometeorology,2019;21(1):68-75.
  12. Chouhan RS, Sundar B, Rashmi V, Khandwe V, Prakash SM. Studies on seasonal incidence and nature of damage of girdle beetle and stem fly in soybean. Journal of Pharmacognosy and Phytochemistry,2019;8(4):3003-3005.
  13. Chaudhary HR, Bajpai NK. Analysis of factors responsible for outbreak of the tobacco caterpillar, *Spodoptera litura* on soybean in humid south eastern plain (zone V) of Rajasthan. Indian Journal of Entomology,2006;68:309-310.
  14. Duncan RG, Walker JR. Some effects of the southern green stinkbug on soybeans. Louisiana Agriculture,1968;12:10-11.
  15. Das GP. Major insect and mite pests of important crops and stored products of Bangladesh. Bangladesh Agric Res Ins,1998. Joydebpur, Gazipur-1701, 102.
  16. Gangrade GA. Insects of soybean. Tech Bull No,24. Directorate of Res Services. JNKV, 1974. Jabalpur. 88.
  17. Garg VK, Patel Y, Nayak MP. Response of kharif legumes to soybean girdle beetle, *Obereopsis brevis* (GAHAN). ABSTRACT Proceeding of Soycon-2014 International Soybean Research Conference on "Mitigating productivity constraints in soybean for sustainable agriculture",2014, 255.
  18. Gadhiya HA, Bhut JB, Vasava SR, Borad PK. Population dynamics of *Helicoverpa armigera* (Hubner) Hardwick and *Spodoptera litura* (Fabricius) on groundnut in relation to weather parameters. Bioinfolet,2014;11(2b):445-447.
  19. Halder J, Seni A. Biological management of major vegetable insect pests with macro and microorganisms. In: Khan MA, Ahmad W, editors. Microbes for Sustainable Insect Pest Management: Sustainability in Plant and Crop Protection. Volume-17, Springer Nature Switzerland AG, 2021, 233-252. [https://doi.org/10.1007/978-3-030-67231-7\\_10](https://doi.org/10.1007/978-3-030-67231-7_10).
  20. Halder J, Majumder S, Rai AB. Compatibility and combined efficacy of entomopathogenic fungi and neonicotinoid insecticides against *Myzus persicae* (Sulzer): An ecofriendly approach. Entomologia Hellenica,2021;30(1):24-32.
  21. Hammond RB, Higgins RA, Mack TP, Pedigo LP, Bechinski EJ. Soybean pest management. CRC Handbook of Pest Management in Agriculture,2nd ed.: D. Pimentel, Ed.: CRC Press Inc. Boca Raton, FL,1991;3:341-472.
  22. Higley LG. Insect injury to soybean. Handbook of Soybean Insect Pests: Higley LG, Boethel DJ, Eds.: Entomology Society of America: Landham, MD, 1994, 11-13.
  23. Horvath AA. Changes in the blood composition of rabbits fed on raw soy beans. J Biol Chem,1926;68:343-355.
  24. Haile FJ, Higley LG, Specht JE. Soybean cultivars and insect defoliation: yield loss and economic injury levels. Agron J,1998;90:344-352.
  25. Herbert DA, Hull C, Day E. Corn earworm biology and management in soybean. Virginia Cooperative Extension, Publication. Virginia Tech: Blacksburg, 2003, 444-770.
  26. Jain N, Sharma D. Evaluation of yield losses by girdle beetle and its management in soybean crop in Kota region, Rajasthan. Life Sci Bull,2011;8(1):123-125.
  27. Jinbo U, Kato T, Ito M. Current progress in DNA barcoding and future implications for entomology. Entomol Sci,2011;14:107-124.
  28. Jat BL, Dahiya KK, Lal R, Niwas R. Effect of weather parameters on seasonal incidence of pod borer complex in pigeon pea. J Agrometeorol,2017;19(3):255-258.
  29. Koenning SR. Southern United States soybean disease loss estimates for 2006,2007: <http://www.cipm.ncsu.edu/ent/SSDW/SSDWloss2006>.
  30. Krishnamurthy K, Shivashankar K. Soybean production in Karnataka. UAS Tech Series No,12. University of Agricultural Sciences: Bangalore, 1975.
  31. Kujur J. Population dynamics of major insect-pests of soybean and management of defoliators and girdle beetle. M.Sc. (Ag.) thesis, Indira Gandhi Krishi Vishwavidyalaya: Raipur, India,2011. pp. 45-46.
  32. Kushram T. Spectrum of insect pest complex and management of major insect pests on soybean (*Glycine max*). M.Sc. (Ag.) thesis Entomology, I.G.K.V.: Raipur,2016;16(1):26-28.

33. Luck FR. Evaluation of natural enemies for biological control: a behavioural approach. *Trends Ecol Evol*,1990;5(6):196-199.
34. Miner FD. Biology and control of stink bugs on soybean. *Arkansas Agric Exp Stn Bull*,1966:70840.
35. Naseri B, Fathipour Y, Moharramipour S, Hosseinaveh V. Comparative life history and fecundity of *Helicoverpa armigera* (*Lepidoptera: Noctuidae*) on different soybean varieties. *Entomol Sci*,2009;12:147–154.
36. Nyffeler M, Sekercioglu CH, Whelan CJ. Insectivorous birds consume an estimated 400–500 million tons of prey annually. *Sci Nat*,2018:105:47.
37. Pedigo LP, Hutchins SH, Higley LG. Economic injury levels in theory and practice. *Annu Rev Entomol*,1986;31:341–368.
38. Patel RM, Sharma P, Sharma AN. Prediction of girdle beetle (*Oberiopsis brevis*) infestation through pest-weather model in soybean. *J Zool Entomol Stud*,2019;7(4):718-23.
39. Punithavalli M, Sharma AN, Rajkumar MB. Seasonality of the common cutworm, *Spodoptera litura* in a soybean ecosystem. *Phytoparasitica*,2013;42:213-222.
40. Ragsdale DW, Voegtlin DJ, O'Neil RJ. Soybean aphid biology in North America. *Ann Entomol Soc Am*,2004;97:204–218.
41. Suyal P. Seasonal incidence of insect pests and their natural enemies on soybean crop. *J Entomol Zool Stud*,2018;6(4):1237-1240.
42. Smith RH, Bass MH. Relationship of artificial pod removal to soybean yields. *J Econ Entomol*,1972;63:606–609.
43. Solanki B, Bharadiya AM, Parmar AM, Bhuva TS. *International Research Journal of Education and Technology*,2022;4(8):2581-7795.
44. Begna SH, Fieldings DJ. Damage potential of grasshoppers (*Orthoptera: Acrididae*) on early growth stages of small grains and canola under subarctic conditions. *J Econ Entomol*,2003;96(4):1193–1200.
45. Todd JW, Jellum MD, Leuck DB. Effects of southern green stink bug damage on fatty acid composition of soybean oil. *Environ Entomol*,1973;2:685–68.
46. Wardle DA, Bardgett RD, Klironomos JN, et al. Ecological linkages between aboveground and belowground biota. *Science*,2004;304:1629-1633.
47. Wrather J, Anderson T, Arsyad D, Tan Y, Ploper L, Porta-Puglia A, et al. Soybean disease loss estimates for the top ten soybean-producing countries in 1998. *Can J Plant Pathol*,2001;23:115–121.
48. Wu ZS, Schenk-Hamlin D, Zhan WY, Ragsdale DW, Heimpel GE. The soybean aphid in China: a historical review. *Ann Entomol Soc Am*,2004;97:209–218.
49. Zeiss MR, Klubertanz TH. Sampling programs for soybean arthropods. *CRC Handbook of Sampling Methods for Arthropods in Agriculture*: Pedigo LP, Buntin GD, Eds.: CRC Press Inc.: Boca Raton, FL, 1994, 539–601.