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Brown marmorated stink bug (BMSB): Introduction, its potential invasion and impact in South Asia

Sushil NyaupaneDOI: <https://doi.org/10.22271/j.ento.2022.v10.i5c.9062>**Abstract**

Brown marmorated stink bug (BMSB), native to East Asia, is an important agricultural and residential pest of serious global concern. Since its first arrival to Pennsylvania in 1996, it has been dispersed in different states of the USA and continues to invade more. Not only in North America, this insect has invaded Europe, Australia, South America, recently to Africa and newer regions of Asia. These insects are reported to be highly efficient in terms of biological characteristics. Furthermore, due to the absence of effective natural enemies in the newly invaded area, these insect's population is building extensively and causing severe damages to various crops. In the newly invaded areas, control options for these pests are limited till now and growers are mostly dependent on broad spectrum insecticides, which is not only costlier but also have negative consequences to the environment and biodiversity at large. Globalized trade has brought the risk of potential spread of this insect species to the South Asian region from the native areas and newly invaded regions. The regions of sub-tropical climate in South Asia may favor brown marmorated stink bug's growth, development and population buildup and could bear losses to proliferating growers of vegetable and fruit crops. Therefore, it is crucial to monitor the movement and spread of this insect species to South Asia by following strong quarantine measures.

Keywords: BMSB, America, invasive, trade, South Asia**1. Introduction**

Brown marmorated stink bug, *Halyomorpha halys* Stal, abbreviated as BMSB, native to East Asia, is an important agricultural and residential pest [1]. In 1996, *H. halys* was detected in Allentown, Pennsylvania, USA, most possibly coming from China in shipping containers [2, 3]. Then, this insect began her journey to disperse in different states of the USA. By 2005, *H. halys* had inhabited several Mid-Atlantic States i.e. Delaware, Maryland, Virginia and West Virginia. It also reached the west coast i.e. California and Oregon [4]. The economic damage due to BMSB was firstly reported in 2006 when it incurred the damage in the soybean field of Pennsylvania [5]. Then after, BMSB started to become a serious pest problem throughout the Mid-Atlantic States. In 2010, devastation to the apple industry reached about \$ 37 million only in those states. As of 2021, *H. halys* has been detected in 47 states in the US and 4 Canadian Provinces in North America. In America only, 10 states are among the ones facing severe agricultural problems and 21 others are facing nuisance problems due to BMSB infestation. The states which are facing this pest seriously in their agricultural field are New York, Pennsylvania, New Jersey, Delaware, Maryland, Virginia, West Virginia, North Carolina, Tennessee and Michigan [6].

From the research, it was confirmed that US *H. halys* were genetically similar to those of Beijing, China [3]. The increase in global temperature will also have certain impacts on invasive species, such as *H. halys* and their response would also be the subject to study. Some of the observed effects on BMSB due to climate change were probable expansion to new areas, higher survival rate during over-wintering, early invasion on spring and shift towards multivoltinism from univoltinism. In Japan, mortality was reduced 15% with a 1°C increase in temperature [7].

This pest has also been reported in Liechtenstein, Germany, Italy, New Zealand, Greece, Hungary, Switzerland, Australia, Canada, Serbia, Romania, Spain, Bulgaria, Russia, Malta and Slovakia [4, 8]. It was also found in Kazakhstan which is a central Asian country [9].

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This pest is also reported in Chile [10]. These all reports signify that this pest has the capacity to cause problems in agriculture globally [11]. Climatic models suggest that this pest can spread to the southern hemisphere and cause problems to agricultural crops [12].

The resurgence of this pest in various regions of the world is motivating the farmers to rely on synthetic pesticides due to the constraint of other effective management strategies. Use of synthetic pesticides as a first resort certainly violates the IPM philosophy at the cost of irrevocable environmental hazards. If we look at the history of use of synthetic pesticides, application of mostly broad spectrum pesticides has inflated by four times in those regions of mid-Atlantic where this pest caused devastation in the orchard industry in 2011. The rampant use of toxic pesticides certainly leads to secondary pests' outbreak due to collapse of natural enemies found in that region [13]. The need to develop a safer ecosystem based management strategy to minimize the impact of this pest is justified well by the above mentioned condition.

2. Taxonomy of BMSB

BMSB is one of the stink bugs, categorized in the Pentatomidae family. These Stink bugs have the special character of producing foul odor when touched or disturbed, which could be offensive to humans [14]. Scientific classification of brown marmorated stink bug is as follows.

Kingdom: Animalia
Phylum: Arthropoda
Class: Insecta
Order: Hemiptera
Family: Pentatomidae
Genus: *Halyomorpha*
Species: *halys*

3. Identification of BMSB

The body of BMSB adults looks like a shield with sizes almost 15 mm lengthwise whereas 8 mm widthwise. These insects have mottled brown and gray color patterns on the dorsal side while having white coloration on ventral side [14] as shown in Fig. 1. The peculiar characteristics of this insect which helps to differentiate with other species of stink bugs

such as brown stink bug is that they have two light bands on terminal segments of antennae [15]. They also possess a blunt (unsharpened) face and a single light band on the legs [16]. Young nymphs have an orange abdomen and black head with an oval shaped body [17]. Matured nymphal stages have darker bodies with light and dark bands on their legs and antennae [2].

4. Life cycle of BMSB

Brown marmorated stink bug overwinters in the human made structures as well as woodlands where they get protection during the entire winter [4]. They come out from the overwintering sites during the spring time but obviously there are many variables that determine their emergence in the field searching for the food. Various environmental parameters play a role activating their metabolism and physiology. It is reported that BMSB exhibits diapause induction in shorter days of photoperiod (12-15 h) whereas longer days (> 15 h) induces its activity and reproduction. Just after coming from the sites where they overwinter, they start to infest plant species and reproduction starts about in two weeks [18]. The frequency of mating observed in BMSB is five times a day with 10 minutes of copulation between the mates [19]. After mating, female insects lay light green eggs in a batch of having 28 eggs on an average. Oviposition occur underside of the leaves of wild host species and cultivated crop species [4]. During her life span, one female insect can lay 243.78 ± 27.48 eggs in laboratory settings [20]. The fecundity of the insect may vary depending on the environment they get and the genetics they inherit [17]. Once mating is accomplished, they have unique features of laying eggs till half of their life but subsequently their capacity to lay eggs decreases as of previous [19].

Reproductively active females of BMSB require extra 147.65 degree days to the requirement of other individuals i.e. 537.63 degree days [20]. In laboratory settings, the emergence of first instar nymphs takes place after 6.9 ± 1.2 days of egg laying [21]. Nymphs undergo subsequent molting with having 5 instars as shown in Fig. 1. Each instar lasts approximately a week but the time period could vary depending on temperature and other environmental parameters [22].

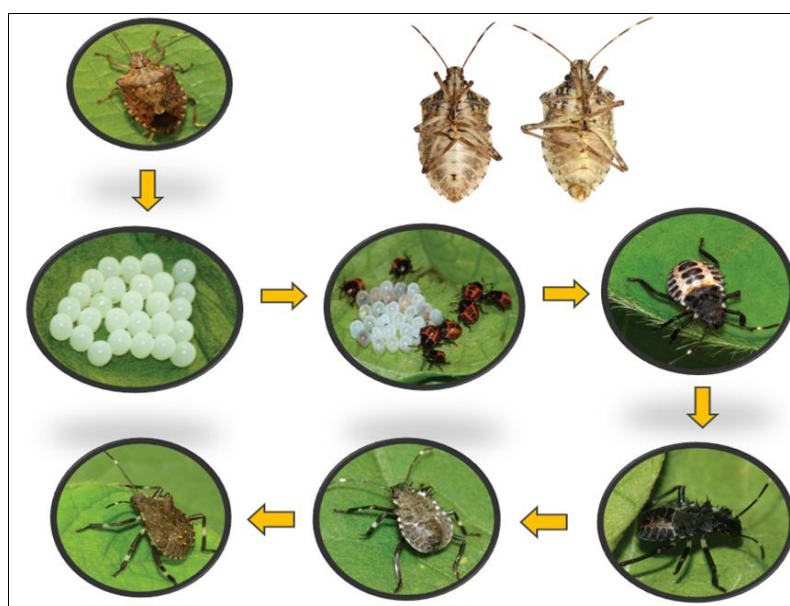


Fig 1: Life cycle of BMSB with subsequent stages (Adult insects -eggs-1st instar- 2nd instar- 3rd instar- 4th instar- 5th instar nymph) (Photo by Ian Grettenberger [4])

5. Host Preference

H. halys is a polyphagous pest which feeds on more than 170 plant species i.e. cereal crops, fruits, vegetables and ornamentals^[4]. More particularly, BMSB feeds on fruits; apple (*Malus domestica*), peach (*Prunus persica*), pear (*Pyrus communis*) and grapes (*Vitis vinifera*), vegetables; tomatoes (*Solanum lycopersicum*), peppers (*Capsicum annuum*), beans (*Phaseolus vulgaris*), eggplants (*Solanum melongena*), cucumber (*Cucumis sativus*) and sweet corn (*Zea mays* var. *rugosa*) including field crops; soybean (*Glycine max*), sunflower (*Helianthus annuus*), corn (*Zea mays*) and wheat (*Triticum aestivum*)^[4, 23]. *H. halys* usually depend on the wild host plants and ornamentals as the early as well as late resources for feeding and breeding before infesting the summer crops or going back to shelter for diapause stage^[24]. Wild and ornamental plants which are more preferred by BMSB are as such: tree of heaven (*Ailanthus altissima*), amaranth (*Amaranthus caudatus*), catalpa (*Catalpa spp.*), eastern redbud (*Cercis Canadensis*), English holly (*Ilex aquifolium*), southern magnolia (*Magnolia grandiflora*), crab apple (*Malus x zumi*), Sargent's crab apple (*Malus sargentii*), Siberian crab apple (*Malus baccata*), mimosa plant (*Mimosa spp.*), white mulberry (*Morus alba*), princess tree (*Princess tree tomentosa*), moth orchid (*Phalaneopsis*

spp.), sweet cherry (*Prunus avium*), cherry plum (*Prunus cerasifera*), Fuji cherry (*Prunus incise*), cherry laurel (*Prunus laurocerasus*), Japanese flowering cherry (*Prunus serrulata*) and winter-flowering cherry (*Prunus subhirtella*)^[25]. Generally wild hosts are exploited by stink bugs as a site for feeding, reproduction and oviposition and also provide ambient space for nymphal development. Most of the stink bug species spend about two third of their life on those host species either for diapause or active physiology i.e. feeding and breeding^[26]. BMSB prefers the plants bearing reproductive structures, such as flowers and fruits, compared to vegetative plant parts^[27] as shown in Fig. 2.

Their selection and preference over different host plants and the resources therein, greatly differs with phenology of the plant^[4, 28]. In soybean, high numbers of *H. halys* have been reported feeding the pod stage as compared to other stages^[28]. This applies with all hemipterans i.e. immature fruits and seeds are more preferred than other stages of preferred host species^[29]. Comparing the number of exploited host plant species for oviposition, nymphal and adult development, *H. halys* infest more and more numbers of plant taxa with its matured stage. *H. halys* exploits more species of angiosperms compared to gymnosperms^[24].



Fig 2: BMSB feeding on experimented corn cob and cowpea pod, North Carolina, USA

6. Host selection and feeding behavior of BMSB

Host selection by the insects usually involves the sequence of events i.e. search for habitat, host/resource acceptance and exploitation of resources. It depends on the perception of insects towards host species and the behavior resulting from that perception^[30]. Color, odor, touch and taste stimulus perceived by the insect play a role for deciding about food resources by the insects. Based on the chemical composition and physical texture of plant species, insects will decide either to come for infestation or go away^[31].

The type of mouth found in BMSB is piercing and sucking i.e. which sucks the sap from plant tissues via stylet^[32]. Like other stink bugs, *H. halys* feed on any visible part of the plants i.e. leaves, stems, petioles, flowers, fruits, seeds, etc. Significant damage is often seen on the fruiting structures as they pierce the plant tissue and suck the sap^[33]. Drinking the sap via stylet by this pest usually leads to the necrosis of the adjacent

cells and tissues, discoloration and in some cases abortion of fruiting structures^[34, 35]. In corn, this pest could feed through the husk causing failure of seed to develop and also results in distorted cob. Whereas in soybean, infestation by this pest may lead to delayed senescence, change in the shape of the pod and change in color^[13, 14]. Additionally, heavy feeding by BMSB on soybean causes delayed maturation of the plant which hampers the growth and development and this is remarkably seen along the borders of the field^[4]. Tomato infestation by BMSB leads to early maturity with development of small fruits with a bitter taste and pithy texture^[33]. In the case of beans, this insect attacks immature seeds of developing pods having some scars and discoloration on the surface^[2].

7. Dispersal capacity of BMSB

Good dispersal capacity is one of the abilities of BMSB for its higher survival and sound nutritional ecology.

They start to disperse to search for food just after finishing their overwintering stay. This equally holds true after spring and summer season to go back to their hiding place with the onset of cold season^[36]. Under laboratory conditions, the mean distance BMSB could fly was more than 5 km during the 24-hour period^[37]. The major objective to disperse from one host plant to another is to meet their nutritional requirements^[38]. Usually adults are capable of long distance flight but they do short flight when disturbed. Nymphs are also reported to have higher migration capacity. Nymphs are able to cross 5 m of length in grassland within 2 hour of time and could crawl 20 m of length in 4-5 hour to arrive at the bait station. 3rd instar nymphs were found to be better walkers than the adults in the laboratory trials^[39]. Adults show high dispersal ability under flight mill experiments conducted in the laboratory i.e. 60 km per day^[38]. This suggests good dispersal capacity of not only adults but younger stages also. Additionally, human aided dispersal is also prevalent throughout the world due to global trade of agricultural and non-agricultural commodities.

8. Potential invasion of BMSB in South Asia

The increased worldwide trade than ever brings the probability of spread of not only the opportunities but also the problems. Due to rapid and efficient exchange routes of agricultural and manufactured commodities, the chances of invasive insect species invasion and its spread throughout the world are rapidly increasing^[40, 41]. Since brown marmorated stink bug's problematic presence is already in five continents i.e. Asia, Europe, North America, South America and Australia, this could become a serious global pest affecting many regions of the globe. Furthermore, BMSB presence in Morocco was reported in 2019 while doing the survey of insect pests of blueberries. This insect's presence is also reported in Algeria of North Africa in the month of July, 2021. It is also expected that due to the pleasant climate of the Mediterranean region, its population is expected to rise in the coming years^[42]. Another article written by a group of researchers has also claimed the probability of further invasion of this species of insect from Russia to other parts of the country and also to Asia^[18].

Being the native of East Asia, this has migrated to newer regions of the world and the recent establishment pathway to central Asian countries like Kazakhstan, it pose a serious threat to other border countries such as Kyrgyzstan, Uzbekistan and Turkmenistan. Since Kazakhstan is a major global producer of cereal grains (wheat, rice and maize), this country exports its produce to more than 70 countries. In terms of monetary value, it shares 2.3% of total wheat export globally, comprising 965.4 USD million^[43]. Since the brown marmorated stink bug is a serious pest of cereal crops, this poses a challenge of pest outbreak in the country. It is also reported that since the introduction of this invasive

species in the country in 2016, presence of stable population and gradual expansion of the range of species, definitely posing a new threat to the agricultural sector of the country^[44].

Increasing trend of global trade of plant and plant products and change in the environment due to climate change, ecosystem degradation, deforestation, etc. is also making the invasive insect species such as brown marmorated stink bug's impact more vulnerable to agriculture. This species of insect is not economical as in found in their natural range i.e. East Asia due to the presence of their natural enemies. This insect's spread throughout the different parts of the world is very rapid. In Europe, this species spread throughout the 30 countries after the first inception in 2004 in Liechtenstein. If we analyze the mode of transmission of this species in England and New Zealand, it was found that this insect migrated in the luggage of passengers traveling by plane. In New Zealand only, this pest has entered the border 83 times in 10 years i.e. from 2005 to 2015, likely through the passing containers of non-biological items or biological items such as plant produce, flowers or nursery saplings, etc.^[45]. Furthermore, it was also found that these insects came in used cars shipped from Japan. In Russia, it is speculated that the non-plant goods imported from foreign countries, especially in winter, brought these insect species into the country^[46].

It is also probable that the countries which do trade with the countries who have established populations, could receive this notorious pest in their traded commodities^[1]. For example, China is the major exporter of fresh apples not only to Southeast Asian markets but to the world at large^[47]. Lack of strong quarantine measures to import apples from China to Southeast Asian countries could result in the invasion of BMSB in those countries. The spread of this insect or any other invasive insect species from this part of the world to Europe is already the case, which is supported by the fact that 40% of all the alien insect species inspected in Europe were reported from Asia^[48]. South Asia is also in coverage by West Asia, Central Asia, East Asia and Southeast Asia and except West Asia, other regions constitute the native range of brown marmorated stink bug so the spread of these insects to the central region (South Asia) could be the case anytime.

The research done based on ecological niche modeling (ENM), predicted that BMSB is suitable in those region lying in between the latitudes of 30-50° N, which includes Northern Europe, Northeastern North America, Southern Australia, North Island of New Zealand, Angola of Africa and Paraguay of South America^[1]. It is also reported that area around the black sea i.e. the region between the Asia and Europe is also good as per the climatic suitability. All the countries of South Asia should be vigilant in exchange of commodities to above mentioned countries in order to follow strong measures in quarantine. With the passage of about 10 years since

then, some of the areas of early prediction have mostly invaded by BMSB and the geographical coverage of pest is burgeoning. According to group of researchers, the area adjacent to China in south i.e. Nepal, northern India consists of light green color, which indicates its moderate suitability in this region^[1]. But, large section of India and other regions of South Asia are showed as of having low climatic suitability to the brown marmorated stink bug. According to the temperature requirement of these insects, they require temperature in between 15-35 °C^[49] and mostly subtropical region of

South Asia is the region where these insects could thrive. The probability of insect spread to South Asian region from the regions of native geographical region (China) and other newly invaded region (Russia and adjacent parts of Asia) is high and shown in Fig. 3. Furthermore, there could be additional chances of BMSB invasion in burgeoning South Asian regions of vegetable and fruit growing areas from the areas where BMSB has been already widespread due to the ever increasing global trade.

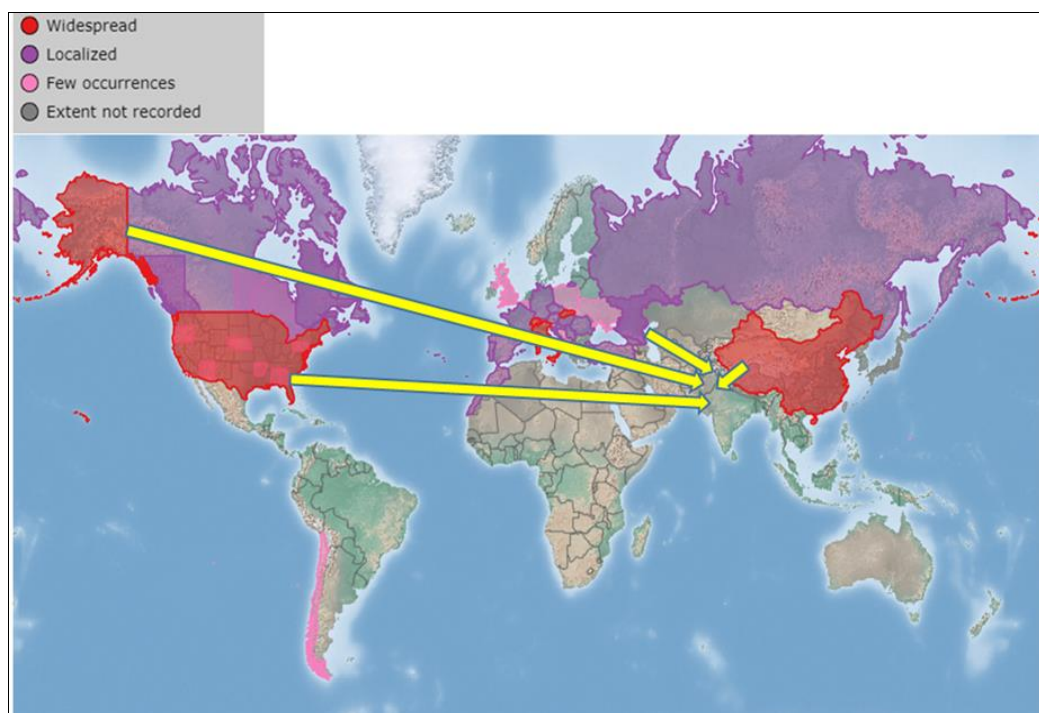


Fig 3: BMSB occurrence throughout the world and its probable migration to South Asia (Source: www.cabi.org)

9. Potential impact of invasion of BMSB in South Asia

Since this pest is polyphagous and could produce two to three generations per year, this insect could reach the pest outbreak level easily causing serious damage to various crops^[50]. Sub-tropical region of South Asia could be the major area where this insect could have the largest impact due to matching of its bio-ecological requirement in the region. The probable invasion of this invasive insect species to South Asia certainly could have ecological and economical losses in the region with additional social consequences.

South Asia is the home of about 1.8 billion people and is a mostly densely populated region of the globe. Since 60% of the South Asian population is primarily dependent on agriculture, it is the important driver of economy and major provider of employment opportunities to its people^[51]. The growing population of South Asia demands more food and it is challenging to maintain food security in the region. So, the impact of polyphagous invasive pests like fall armyworm, brown marmorated stink bug, etc. on agricultural crop production could be higher and problematic for South

Asia. This pest could have an impact on the South Asian economic export earnings from various crop species. Crop damage and management cost of the brown marmorated stink bug will certainly reduce the profitability of growers and challenge their socio-economic status.

If invaded by this pest, it looks like a chemical method of pest management is the only reliable strategy for reducing its infestation and damage. In the regions of America, farmers are purchasing more chemicals than previous year to prevent the damage from this species of insect. Mostly broad spectrum pesticides such as pyrethroids, neonicotinoids, carbamates, organophosphate, etc. are in use in those regions^[4]. One of the devastating effects of these pesticides is that they reduce the natural enemies' population and cause the outbreak of secondary pests. Another problem of invasive insect species is that due to the lack of effective natural enemies in newly invaded area, the problem of these insect species could be more intense to crops and other host species. So, the natural enemies of native areas should also be introduced to the newly invaded areas to manage these sorts of invasive insect species.

Furthermore, the brown marmorated stink bug is not only an agricultural pest, but also a nuisance pest which could affect people by invading their homes and valuable structures in the winter season.

10. Conclusion

Despite of native to East Asia, Brown marmorated stink bug (BMSB) has invaded North America, South America, Europe, Australia, Africa and new geographical areas of Asia as well. Biological characteristics enable this insect to be highly successful not only in native range, but also to the newly invading regions. Being a serious pest of global concern, there is a high risk of invasion of this species of insect to the South Asian region. Climatic factors in some regions of South Asia, especially of having sub-tropical climate, permit the favorable growth, development and population buildup of BMSB. Sharing the boundary with native region of BMSB, South Asian countries should be extra vigilant to follow strong quarantine measures to check its unwarranted arrival.

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