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Research Article

Efficacy of augmentative release of the parasitoid wasp *Bracon hebetor* against the pearl millet headminer

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ABSTRACT: The yield losses in pearl millet, estimated to be about 85%, are mainly due to millet headminer, *Heliocheilus albipunctella.* This study is aimed at determining the status of this serious insect pest in the pearl millet production system within the groundnut basin of Senegal and to assess the efficacy of augmentative releases of its parasitoid wasp, *Bracon hebetor,* to control it. The study area was divided into three homogenous blocks (Northern, Southern and Eastern parts) where a set of three villages was selected for release of the parasitoid and another three as control villages where no releases were made. The results revealed that in all the villages where the parasitoid was released, an increase in larval mortality due to parasitism ranging between 9% and 26% was recorded in comparison with the control villages. Consequently, damages recorded were significantly lower in the villages with parasitoid releases.

KEY WORDS: Augmentative release, biological control, *Bracon hebetor*, millet headminer, pearl millet

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INTRODUCTION

Pearl millet (*Pennisetum glaucum* (L.) (R. Br.) is one of the main cereal crops widely cultivated in the Sudano-Sahelian regions of West Africa. It is a hardy crop which can grow on low soil fertility and is able to produce grains in harsh climatic conditions (Nwanze and Harris, 1992). Despite its adaptation to extreme climatic conditions, pearl millet is still hampered by many biotic constraints including damage by insect pests. In the West African region including Senegal, the pearl millet headminer (MHM), *Heliocheilus albipunctella* (De Joannis) (Lepidoptera: Noctuidae) and the millet stem borer, *Coniesta ignefusalis* Hampson (Lepidoptera: Pyralidae) are the most economically important insect pests of pearl millet causing extensive damages (Jago, 1993; Nwanze, 1991; Gahukar, 1984). However, based on damages, the MHM is the most injurious, causing direct grain loss up to 85% due to flower abortion or grain spilling (Payne *et al*., 2011; Youm and Owusu, 1998; Nwanze and Sivakumar, 1990; Ndoye and Gahukar, 1989; Gahukar *et al*., 1986).

Management strategies including cultural methods, host plant resistance and the use of pesticides have been tested with limited success and applicability (Payne *et al*., 2011; Sarr, 1998; Ajayi, 1990; Gahukar, 1990b; Nwanze and Sivakumar, 1990; Gahukar *et al*., 1986). Biological control with the release of natural enemies has been used as one of the alternatives to pesticides (Van Lenteren, 2012; Overholt *et al.,* 1997; Smith, 1996). These natural enemies are being widely used for the management of insect pests. At least 230 species of natural enemies were used in augmentative biological control programs against a variety pests worldwide (Van Lenteren, 2012). In the Sahel, *Bracon (Habrobracon) hebetor* (Say) (Hymenoptera: Braconidae) is one of the most promising biological agents for the control of MHM. In the late eighties, and to a certain extent in recent years, up to 95% larval parasitism by *B. hebetor* at the end of the pearl millet cropping season was recorded in the Sahel region when damage had already occurred (Ba *et al*., 2013; Payne *et al*., 2011; Nwanze and Harris, 1992; Bhatnagar, 1989). Augmentative releases of *B. hebetor* for the control of MHM in famers' fields have been effective in many Sahelian regions as demonstrated by significant mortality of larvae with a parasitism rate up to 97% and an increase in grain yield up to 50% (Amadou *et al*., 2017; Kabore *et al.*, 2017; Ba *et al*., 2014; Baoua *et al*., 2014; Ba *et al*., 2013; Payne *et al.*, 2011; Bhatnagar, 1989).

Since the first attempt of augmentative releases of *B. hebetor* in Senegal in the early eighties, its implementation is still at a small scale level and there is a need for expanding it for a better area-wide control of MHM.

The aim of this study is to determine the actual status of the millet headminer in the pearl millet sub-agro-ecological zones within the groundnut basin of Senegal and to assess the efficacy of augmentative field release of *B. hebetor* to control MHM in farmer fields.

MATERIALS AND METHODS

Study area

This study was conducted during the 2015 cropping season in the groundnut basin of Senegal which is the main production area of pearl millet located in the centre of the country. In this region, the annual rainfall varies between 400 to 500 mm in the northern part and 600 to 800 mm in the southern part.

The study area was divided into three homogeneous blocks in the northern, southern and eastern parts according to agro-ecological zones (Fig. 1) where a set of three villages was selected randomly of which three were earmarked for releases of the parasitoid and the other three as control where no releases were made. These selections were made, using geographic information systems with the Senegalese administrative limits, roads and village layers and remote sensing techniques. Distance between blocks was at least 20km and 5km between villages in the same block.

Mass rearing of insects

The Mediterranean flour moth, *Ephestia kuehniella* (Zeller) (Lepidoptera: Pyralidae), was used as a laboratory host to establish and maintain a colony of *B. hebetor* in the entomology lab of Nioro du Rip under ambient conditions. The newly emerged adults of *E. kuehniella*, were confined in Plexiglas cages with the bottom side replaced with a net cloth to enable collecting eggs laid by females through the meshes of the nets. About 500 eggs were harvested daily and transferred into petri dishes (15cm diameter x 2.5cm depth) filled with a mixture diet consisting of 2/4 pearl millet grain and 1/4 flour. The diet was previously sterilized in an oven at 100°C for 24 hours in advance. Subsequent generations in the previous containers were transferred to a wooden cage for which three sides were wire-netted and where an equivalent of one gram of food per larva was placed.

For *B. hebetor*, the newly emerged adults were collected, confined in a wooden cage and supplied with a 10% sucrose solution in soaked cotton wool. The lid of the cage was replaced by a glass; manipulation inside was possible through a hole made on one side of the cage and covered with cloth netting. Two mated females of *B. hebetor* were collected and confined with 20 larvae (third instar) of *E. kuehniella* in a petri dish (10 cm diameter x 1.5cm depth) for 48 hours. Subsequent generations of *B. hebetor* emerging in 5 to 12 days later were placed in a wooden cage to maintain the colony.

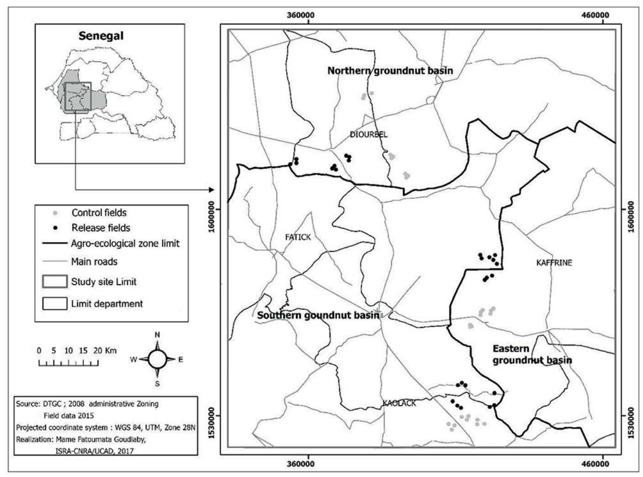

Fig 1. Field release sites and control villages in the groundnut basin of Senegal.

To avoid the colony of insects to collapse due to self-sterility or male biased sex ratio, new host insects and parasitoids were periodically collected from the granaries and added to maintain a good production of female offspring.

Field releases

For the parasitoid releases, 20 larvae (third instar) of *E. kuehniella* were confined with 3 females and 2 males of *B. hebetor* 48 hours prior to field releases. In the field, parasitized larvae were placed in jute bags of 15cm x 25 cm (Ba *et al*., 2014) containing 100g of millet grain. Jute bags were hung on three stakes *i.e.* release points from where diapausing parasitoids emerged to disperse in the pearl millet field to parasitize the MHM larvae.

In each block, a Completely Randomized Block Design (CRBD) was adopted with two treatments. The control corresponded to a set of three villages with no release and a release treatment with set of three villages where parasitoids were released at pearl millet flowering and filling stages. Within treatments, five pearl millet fields belonging to farmers, at a distance of 2 km, were chosen per village in a farmer participatory way through the chief of village. Villages within a treatment were 5 km away from each other. Between the control and the released fields, the distance was at least 20 km.

Relative importance of MHM in comparison with stem borers

For all blocks, 12 hills from each farmer's field were randomly selected and the number of plants infested by either the stem borer or MHM was recorded.

The relative importance (RI) of MHM was estimated.

$$RI(\%) = \frac{Number\ of\ infested\ plants\ by\ MHM}{Sum\ of\ plants\ infested\ by\ stemborer\ and\ MHM} \times 100$$

Incidence of the MHM

For assessing the incidence of MHM, likewise, 12 hills from each farmer's field were randomly selected in all blocks and the number of plants infested by MHM was recorded. The estimation of MHM incidence was done as per the following formula:

$$I(\%) = \frac{Number\ of\ infested\ earhead\ by\ MHM}{Total\ number\ of\ sampled\ plants} \times 100$$

Parasitism and damages by MHM

The extent of parasitism by *B. hebetor* was estimated at the maturity stage of pearl millet earheads. In each farmer's field, 60 pearl earheads were randomly taken and the number of living larvae (unparasitized), parasitized larvae or cocoons in the mines was recorded. The number and the length of mines were also recorded on all sampled pearl millet earheads.

The parasitism rate (P) of MHM was estimated using the following formula:

$$P(\%) = \frac{Number\ of\ parasitized\ larvae}{Total\ number\ of\ collected\ larvae} \times 100$$

Data analysis

The different variables were subjected to ANOVA using the General Linear Model (GLM) with Student Newman Keuls for the mean separation test at a probability level $\alpha = 0.05$. Prior to the analysis of variance and for eliminating heterocedasticity, data were transformed using $arcsine\sqrt{i+0.5}$ and $\log_{10}(x+1)$ where i = incidence (proportion) or parasitism rate and X = count variables *i.e.* number of mines and length of the mines(McDonald, 2009). All analyses were performed using the software SAS 9.1 (SAS, 2003) and results are presented as mean ± standard error.

RESULTS AND DISCUSSION

Relative importance of the MHM

Overall, the MHM was the most common insect pest in all blocks and represented 80% of the samples compared to stem borers. The relative importance of the infested samples by MHM was 90%, 80% and 74% in the northern, southern and eastern part of the groundnut basin, respectively. The stem borer infestation was low and varied between 10 and 26% for all blocks (Fig. 2). The low occurrence of stem borers, particularly *C. ignefusalis* contrasted with many finding which considered this pest as economic pest, common in pearl millet fields (Drame-Yaye *et al.*, 2003; Nwanze and Harris, 1992; Youm *et al.*, 1996).

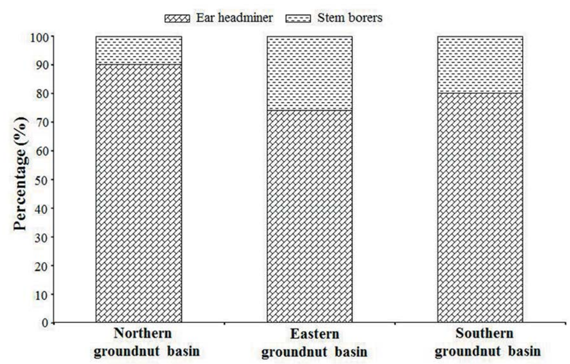

Fig. 2. Relative importance of millet headminer and stem borers in three locations of the groundnut basin of Senegal.

Incidence of the MHM

The MHM incidence was high and varied between 60.94±4.02% and 84.97%±3.37% according to locations. It was significantly higher (P<0.05) in all locations except for the northern groundnut basin where the MHM incidence was low compared to the eastern and southern parts (Fig.3). The high frequency and incidence recorded confirmed the key pest status of the MHM in pearl millet agroecosystem of Senegal. In the late 1970s,Vercambre (1978) recorded high pearl millet damage due to MHM in this region. Further studies on pearl millet also confirmed MHM to be an important pest in Sudano-sahelian West African region (Owusu *et al.*, 2004; Lale and Sastawa, 2000; Harris, 1995; Ndoye, 1991; Gahukar *et al.*, 1986). The variability of the MHM incidence and abundance of stem borers could be due to the differences within the agro-ecological zones including the rainfall patterns, the incidence of egg parasitism, type of cultivars grown, date of planting which influences the flowering period as well as cultural practices used by the farmers (Goudiaby *et al.*, 2018; Lale and Sastawa; 2000). In fact, the presence of the egg parasitoid, *Trichogrammatoidea armigera* Nagaraja, may have contributed in reducing the MHM population in the northern blocks. Another reason could be that some farmers grow Thialack variety which has exhibited natural resistance to MHM (Goudiaby *et al.*, 2018). Yet another reason could be that if the planting date is altered, it would break the synchrony between pearl millet flowering and emergence of MHM, thereby resulting in low incidence.

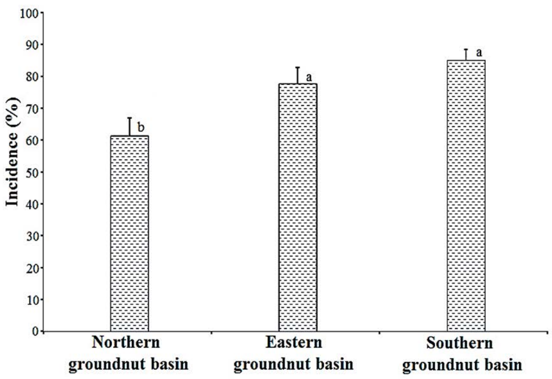

Fig 3. Incidence (mean±SE) of the millet headminer in three blocks within the groundnut basin of Senegal (Means followed by the same letters are not significantly different at α= 0.05).

Bracon hebetor **parasitism rate on MHM**

Parasitism rate due to *B. hebetor* was very high in the control fields in the northern basin with 85% larval mortality compared to low rate recorded in the eastern (3%) and southern (15%) basins (Fig. 4). The lower natural parasitism of *B. hebetor* found in eastern and southern groundnut basins suggested the existence of a low population abundance of the parasitoid to control the MHM as the population of this pest is higher in a pearl millet agro-ecosystem. In a previous study conducted in Senegal, natural parasitism by *B. hebetor* ranging between 2 to 19% was recorded in pearl millet fields (Bhatnagar, 1989). A low larval mortality due to *B. hebetor* has been also recorded on the MHM in Niger, Mali and Burkina Faso (Ba *et al.*, 2013) and on some fields lepidopterous species (Saxena *et al.*, 2012). In the Sahelian region, the harsh offseason weather does not permit maintenance of normal population of parasitoids as semi-natural habitats and alternate hosts are rare particularly during the dry season (Ba *et al.*, 2014). Many agroecosystems are unfavourable environments for natural enemies due to high levels of disturbance and the lack of resources in agricultural landscapes (Jonsson *et al.*, 2014; Bianchi *et al*., 2006; Landis *et al.*, 2000; Altieri, 1999). The high natural parasitism found in control villages in the northern groundnut basin could be explained by the surrounding environment such as the presence of many granaries that support lepidopteran species which serve as alternate hosts for *B. hebetor* (Ghimire and Phillips, 2010a; Ghimire and Phillips, 2010b; Milonas, 2005; Heimpel *et al.*, 1999). *B. hebetor* survived the dry season by parasitizing the flour moth, *Ephestia spp.,* as has been found in Senegal (Bhatnagar, 1989). The high natural parasitism recorded in the northern groundnut basin was probably due to *B. hetetor* coming from surrounding granaries and grain stores. However, some findings suggested that storage strain of *B. hebetor* performed poorly in the field (Ba *et al.*, 2014; Saadat *et al.*, 2014). Also, the variability observed among locations (northern, southern and eastern groundnut basin) might be due to the variability in the rainfall pattern within different of agro-ecological zones as well as cultural practices adopted by farmers.

In all locations, the parasitism level was higher in release fields compared to control and varied between 95.07±0.02% and 33.33±4.22% according locations (Fig.4). The increase in parasitism levels ranged between 9 and 26% within all locations with the highest ones recorded at the eastern and southern groundnut basin (Fig. 4). The augmentative release of *B. hebetor* significantly increased the mortality level of MHM in farmer fields. This concurred with its potential biocontrol of field and stored lepidopterous insect pests mentioned in many studies (Kabore *etal.*, 2017; Ba *et al.*, 2014; Ghimire and Phillips, 2014; Saadat *et al.*, 2014; Saxena *et al.*, 2012; Adarkwah *et al.*, 2010; Ghimire and Phillips, 2010a, 2010b; Amir-Maafi and Chi, 2006; Bhatnagar, 1989). Overall, the parasitism level by *B. hebetor* was low with an average of 31% compared to the high larval mortality ranging between 50% to 78% obtained in previous studies in Senegal (Bhatnagar, 1989) and a parasitism rate as high as 97% recorded in Niger, Burkina Faso and Mali (Ba *et al.*, 2014; Ba *et al.*, 2013).

Damages by MHM

The damage in terms of number of mines recorded per earhead (*i.e.* panicle) was significantly low (P<0.05) within the release fields located in the eastern and southern groundnut basin with 2.22±0.22 mines and 2.78 ±0.36 mines, respectively (Figure 5 A). For fields located in the northern side of the groundnut basin, no significant difference was found in the number of mines between control and release fields. In the southern basin, the damage by MHM in terms of length of mines bored was significantly lower (P<0.05) in the release fields with 3.14±0.29cm compared to the control (Figure 5 B). However, the mines were short in the release fields in the northern (3.78±0.17cm) and eastern

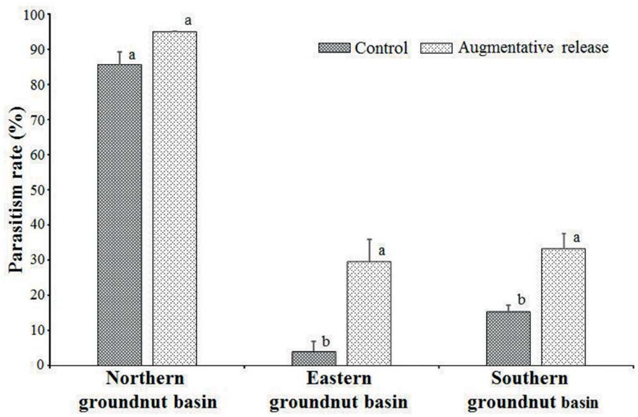

Fig 4. Parasitism of the millet headminer in control and augmentative release fields in three blocks within the groundnut basin of Senegal. (Means followed by the same letters are not significantly different at α= 0.05).

(4.03±0.28cm) parts of the groundnut basin. This reduction was not significant compared to the control (Figure 5B).

The increased parasitism rate in the release villages significantly reduced the MHM damages due to the control of the larvae. In recent studies, a reduction in grain yield losses from millet infested panicles increased up to 50% and was recorded as a result of an effective

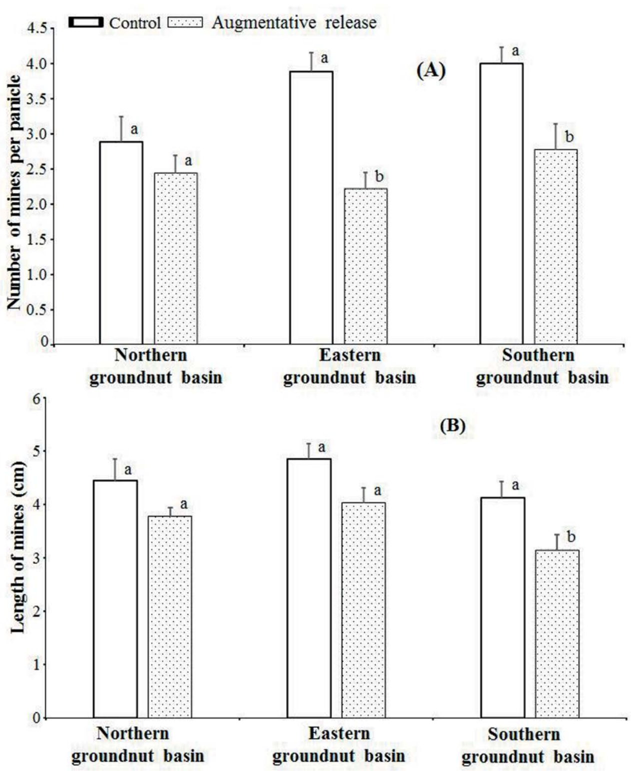

Fig 5. Mean (±SE) number (A) and length (B) of mines due to the millet headminer in the control and augmentative release fields in three blocks within the groundnut basin of Senegal (Means followed by the same letters are not significantly different at α= 0.05).

parasitization by *B. hebetor* (Amadou *et al.*, 2017; Baoua *et al.*, 2014)

Overall, MHM has been found to be the most prevalent insect pest of economic importance in the pearl millet agroecosystem of Senegal. The natural parasitism by *B. hebetor* was low except in some locations where the parasitoid could probably maintain its population during the dry season on alternate hosts infesting cereals stored in stores or granaries. The augmentative release was effective, increased the MHM larval mortality and reduced damage in all locations.

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