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Effect of Distance from Wetland Borders on Hymenopteran Wasps and Spider Abundance in Maize-soybean Cropping System

David Ojuu [a*], Samuel Kyamanywa [a] and Thomas Odong Lapaka [a]

[a] Department of Agricultural Production, Makerere University, P.O. Box-7062, Kampala, Uganda.

Authors' contributions

This work was carried out in collaboration among all authors. Author DO conceptualised and developed the research idea, conducted field experiments, collected data and wrote research findings. Authors SK and TOL reviewed the research concept and final write-up. Author TOL supported in the analysis of research data. All authors read and approved the final manuscript.

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ABSTRACT

The non-crop habitats within agroecosystems are important resources for ecological and biological insect pest management. Diversified cropping systems are known to influence pests populations, however, how neighboring habitats to the agricultural fields affect insect pest natural enemies population dynamics is not clear. This study focused on understanding the influence of wetland borders on Hymenoptera wasps and predatory spider prevalence in a maize-soybean intercrop system. The Hymenoptera wasps and spiders population estimates were carried out in twelve farmers' fields stratified within 0-300 and 500-1100 meters from the wetland borders. Data were collected once a week starting one week from the emergence of maize and soybean plants until post-flower growth of the two crops. Results showed crop fields within 0-300 meters from the wetland borders had significantly higher numbers of wasps and spiders, while crop fields set up at

**Corresponding author: E-mail: davidojuu@gmail.com;*

500-1100 meters from the wetland borders, the population of Hymenoptera wasps and spiders was significantly reduced. The findings of this study indicate that stable habitats such as wetland borders harbour higher numbers of natural enemies of crop pests and crop fields at close proximity benefit from quick migration of natural enemies from the pool in stable habitats. These findings can be used to design field architectures such as field margins or borders that can support insect pest natural enemies survival and migration into crop fields.

Keywords: Wetland borders; wasps; spiders; population estimates; maize-soybean intercrop.

1. INTRODUCTION

"In peasant dominated areas, the use of traditional farming practices has resulted in a varied, highly heterogeneous landscape possibly even more heterogeneous than would exist naturally" [1]. Globally there is wide scale conversion of natural habitats into crop land; this consequently is affecting biodiversity across spatial and temporal scales [2]. The ecosystem services of crop pest regulation have been compromised and thus influenced farming communities' decisions on massive chemical pesticide sprays [3]. Moreover, the use of chemical pesticides is damaging to the environment by affecting biodiversity, affects human health and is considered to be unsustainable option for resource-constrained farmers.

Non-crop habitats serve as key resources for agroecologies due to great biodiversity they harbour. Landscape studies reveal that complex landscapes with large proportions of semi natural habitats have positive effects on natural enemies' abundance and diversity [4]. The increased abundance and diversity influence herbivore pest numbers in crop fields [5]. It has been observed for instance that natural enemies may attack prey populations in crop fields but fail to keep pest numbers in these ecosystems at low levels [6]. In this regard, effective pest suppression may depend on constant supply of colonists from adjacent stable habitats [2]; therefore, source-sink relationship may influence the spatial and temporal spill over effects and pest populations in adjacent agricultural fields.

Studies on beneficial insects have focused on terrestrial habitats such as forest edges or grassy strips [7,8,5], while those that have attempted to understand effect of wetland borders on natural enemies in crop fields have focused on finer spatial scales [9,10]. Wetland borders can be a sink of fertilizers from agricultural fields and may promote plant and floral diversity, providing alternate hosts for agricultural field crops and favourable microclimate that can support larger populations of beneficial arthropods [11].

"The temporal dynamics specifically can affect spill-over effects of insect pests natural enemies within the ecosystem. It is observed that cultivated patches often experience decline in resources due to continuous crop harvests, thus natural enemies emigrate to semi-natural and natural patches [12]. Therefore, semi-natural and natural habitats thus play a significant role of serving as points for species development and survival during periods of low resources availability. The stable natural and semi natural habitats serve as starting points for colonization of crop fields by insect pests and natural enemies at the start of a cropping season [13]. The interface between natural and semi natural habitats ensures that crop fields proximate enough benefit more from natural enemies that have low dispersal capability but also those with great flight ability, whose sustained survival in the new habitats may not be assured.

Some beneficial arthropods are limited by dispersal abilities and their effectiveness to keep pest populations at low numbers in agricultural fields depends on constant supply from stable non-crop habitats that are large and proximate enough. Also the effective dispersal and efficiency to keep pest population on check can be enhanced by agricultural field margin type. What however, is not well researched is how far the effect of wetland borders on Hymenoptera wasps and spider abundance in complex agroecosystems such as those provided by Maize and soybean intercrop can extend. Therefore, this study was conducted to understand the influence of wetland borders on the abundance of Hymenoptera wasps and predatory spiders in a maize-soybean intercrop.

2. METHODS AND MATERIALS

"The study was conducted in Iganga District (Eastern Uganda). The district lies in the Kyoga plains agroecology, one of the five agroecologies of Uganda. The study was specifically carried out in Namalemba Sub- County, Namalemba parish in the Naigombwa wetland system, a tributary of the Mpologoma river of the Lake Kyoga basin (MWE, 2016). Naigombwa wetland is located at 00.72963^{0}N, 033.58718^{0}E and about 22km from Iganga town along Iganga-Mbale road. Being the biggest wetland in the district, a lot of agricultural production is carried out around its catchment and thus provided a good opportunity to conduct the study of pest and natural enemies' activity in relation to field distance from the wetland borders" [14].

Farmers to host the study were selected through stratified (those whose fields lie in the study distance from the wetland borders) and snowball (A selected farmer within the distance stratum helps to identify another within the same stratum) sampling techniques. The study was conducted in twelve farmers' fields that were selected by use of stratified and snowball sampling techniques. The study fields were considered within a distance of 1100 meter from the wetland boarder and were stratified according to distance from the wetland border inland. Two strata of 0-300 meters and 500-1000 meters from the wetland borders were considered; the first stratum had six crop fields selected from within three distance levels of; 0-50 meters; had two crop fields sampled; 51-100meters had two crop fields sampled and 101-300meters had two crop field sampled in that order from wetland border. The second stratum also had six fields selected within three distance levels of; 500 - 699 meters had two crop fields sampled, 700 - 899 meters had two crop fields sampled and 900-1099 meters had two crop field sampled in that order from the wetland border.

"The exact distances of each crop field from the wetland borders were established by taking coordinate readings from the field center using Geographical Positioning System (GPS). Later the geographical distances between the fields and wetland borders were calculated using package geosphere in R statistical software" [15]. The function "distVincentyEllipsoid" which measures the shortest distance between two points, according to the 'Vincenty (ellipsoid)' method (Vincenty, 1975) was used.

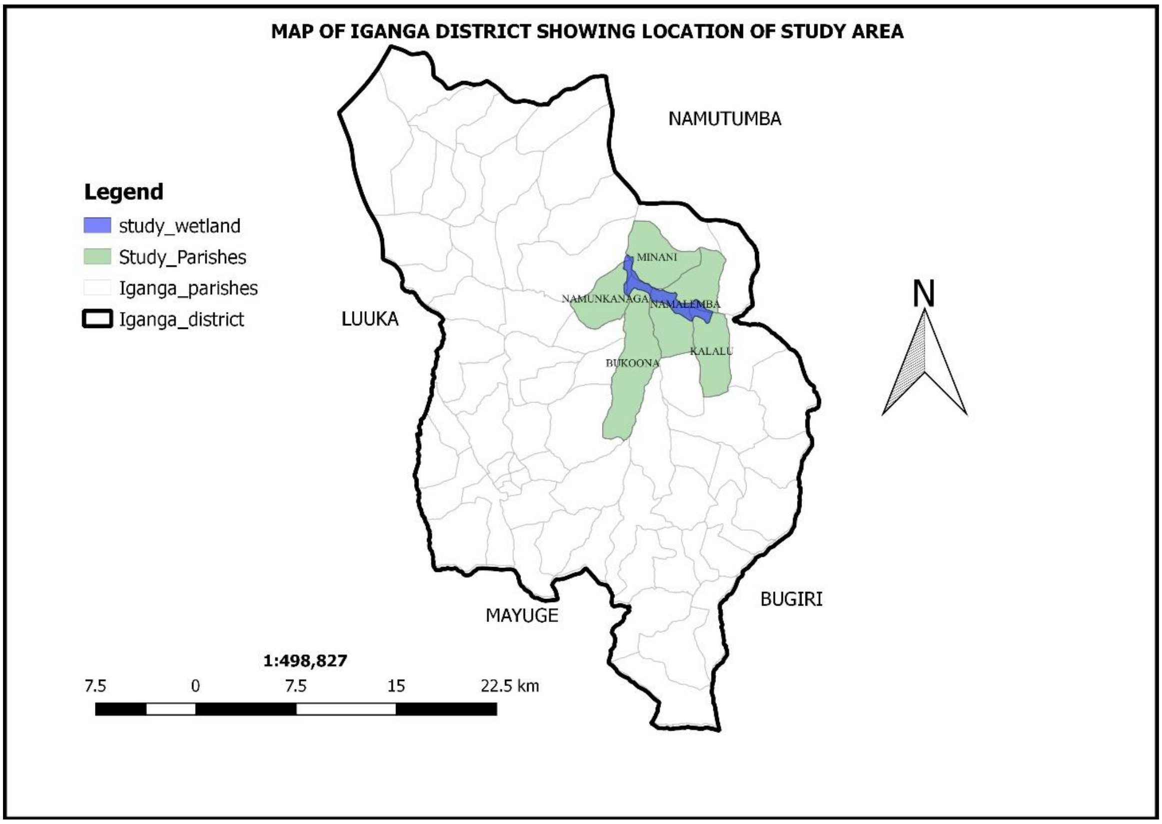

Fig. 1. Map showing the study location

"The selected farmers were given the same maize variety (Longe 5) and soybean variety (Maksoy 5N). Considering a common practice of intercropping maize and soybeans in the study area, farmers were only guided by the researcher to plant and manage their intercropped fields using standard agronomic practices. The intercrop ratio of 2 rows of maize followed by 2 rows of soybean (2:2) was used for planting maize-soybeans; maize was planted at a spacing of 90cm between rows and 50cm between plants within a row with two plants per hill while soybean was planted at spacing of 50cm between rows and 10cm between plants within a row and one plant per hill was used. The planting pattern and spacing used was uniform across all the study fields. To ensure validity of the study, farmers were advised to prepare and plant crop fields early so that timely planting could ensure effective plant growth when the pest populations were low and thus chemical sprays were discouraged in the study fields" [14].

The study was conducted for two cropping seasons of 2017A and 2017B; experiment in season 2017A was conducted in the month of; March to June while the experiment in season 2017B was conducted in the months of August to November.

2.1 Sampling of Hymenoptera Wasps and Spiders

Relative abundance of Hymenoptera wasps and predatory spiders was studied in the wetland vegetation and crop fields by; (a) Sweep net sampling above crop and vegetation canopy [16]. For sweep net sampling in each crop field within the stratum, a zigzag movement pattern across two field diagonals was used and five sweeps were considered to constitute one sample and a total of four samples were taken. To prevent insect escapes as well as biting behaviour, the trapped wasps and spiders were killed in a jar containing cotton wool impregnated with Chloroform and later the insects were transferred to preservative glass vials enriched with 96% ethanol. At the wetland borderline, a Zigzag movement pattern within 10 meters width of the transect were taken and five sweeps in a given diagonal constituted one sample. The length of the sampling transects at the wetland border corresponded with the cumulative width of the six fields within the first 0-300 meters stratum from the wetland border. Sweep net sampling was done every two weeks for a period of three months.

(b) Pitfall trapping for predatory spiders was done at the wetland borderline and crop fields to determine the activity of predatory spiders [17]. Twelve pitfall traps at distance intervals of 20meters were installed along the wetland borders with rims at ground level. In each crop field, six pitfall traps were installed across field diagonals at standard spacing of 20meters apart. The plastic containers were half filled with ordinary water enriched with 1ml of Formalin 40% for preservation of trapped insects. The constituents of the traps were emptied every seven days and insects transferred to glass vials containing 96% ethanol. The seven days interval was considered ample enough to allow for insects trapping and for the researcher to effectively move across all the twelve farmers' fields that were dispersed over a significant areas of the wetland borderlines.

(c) Water trapping; Water traps consisting of white and yellow colours were used to study activity of Hymenoptera wasps and predatory spiders [18]. Six Water traps (Three yellow and 3 white) were set along fields diagonals at least 10 meters from the field margins. The water traps were set at standard distance of 20 meters apart and were filled 75% with Formalin 40% enriched water. The trapped insects were transferred to ethanol rich glass vials every 7 days.

Data collected from the study was subjected to GenStat analysis package 14th Edition, to generate descriptive statistics such as means and conduct analysis of variance (ANOVA) depending on the field stratification. Mean significant differences in Hymenoptera wasps and spiders abundance between wetland borders and crop fields was tested using LSD at 5% significance level. Data of every study season was analysed separately due to differences in seasonal conditions that could also affect natural enemies dynamics.

3. RESULTS AND DISCUSSION

3.1 Hymenoptera Wasps

Analysis of variance showed that across the two seasons of study (2017A and 2017B), there was a significant ($P<0.001$) effect of crop distance from the wetland borders on the relative abundance of Hymenoptera wasps. Crop fields closer (82-219 meters) to the wetland borders registered the higher mean densities ranging 15-23 and 12-27 wasps/field for seasons 2017A and 2017B respectively while fields furthest from the wetland borders (568-1096 meters) registered low mean densities ranging 2-12 and 6-13 wasps/field in seasons 2017A and 2017B respectively (Fig. 1).

Furthermore, regression analysis showed a strong linear relationship between wasps abundance and crop field distance from the wetland borderline was observed in both seasons 2017A and 2017B, as crop field distance from the wetland border points increased, population of wasps significantly reduced (R^2=0.8447 in season 2017A and R^2=0.5397 in season 2017B) (Fig. 1).

3.2 Predatory Spiders Abundance

Crop distance from the wetland borders significantly (P<0.001) affected spiders abundance; crop fields closer to the wetland borders (82-219 meters) registered high abundance of spiders, while crop fields further from the wetland borders; 568-1096 meters registered significant reduction in spider populations by a margin of 14 and 23 spiders/field in seasons 2017A and 2017B respectively (Fig. 2). A more linear reduction of spider abundance was observed in season 2017B as compared to season 2017A that was characterised by fluctuations in spider numbers as distance from wetland borders increased. Regression analysis showed that there was a linear relationship between crop field distance with spider abundance where a strong linear relationship was observed in season 2017B (R^2=0.8426 than 2017A (R^2=0.1663) (Fig. 2).

3.3 Interface between Wetland Borderline and Crop Field Hymenoptera Parasitoid Wasps and Spider Population Dynamics with Sampling Time

Overall, the study period; 2017A and 2017B, 501 natural enemies were collected and hymenopteran ants (*Formicidae*) constituted 39%, Hymenoptera parasitoid wasps accounted for 31% and Predatory spiders (*Arachnidae*) 30% the dominant families of spiders collected included Lycosidae and Linyphiidae. It was observed that in both seasons 2017A and 2017B the Hymenoptera wasps population at the wetland borderline was high at the beginning of the experiment. The increase in sampling time (sampling 3-5) in season 2017A registered a significant build-up in wasp populations in crop fields within 219 meters from the wetland borderline. Similarly, in season 2017B, increase wasp populations crop fields within 219 meters from the wetland borderline was observed as sampling time increased (Fig. 1). Across the study seasons, high spider abundance at the wetland borders was registered at the beginning of sampling and further increase in sampling time, witnessed a significant decrease in spider populations from the wetland border (Fig. 3) and increasing spider population were recorded in crop fields within 174 meters from the wetland borderline (Fig. 2).

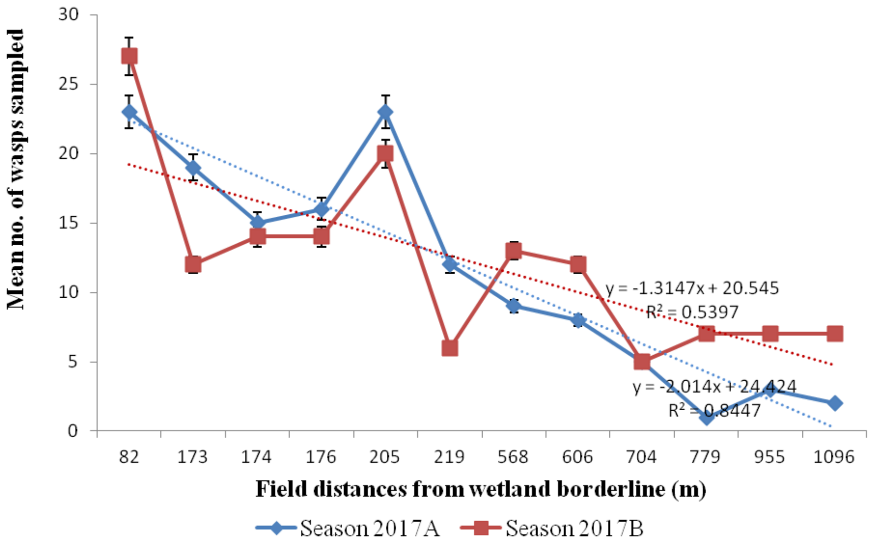

Fig. 2. The relative abundance of Hymenopteran wasps per field at different sampling distances from the wetland borders

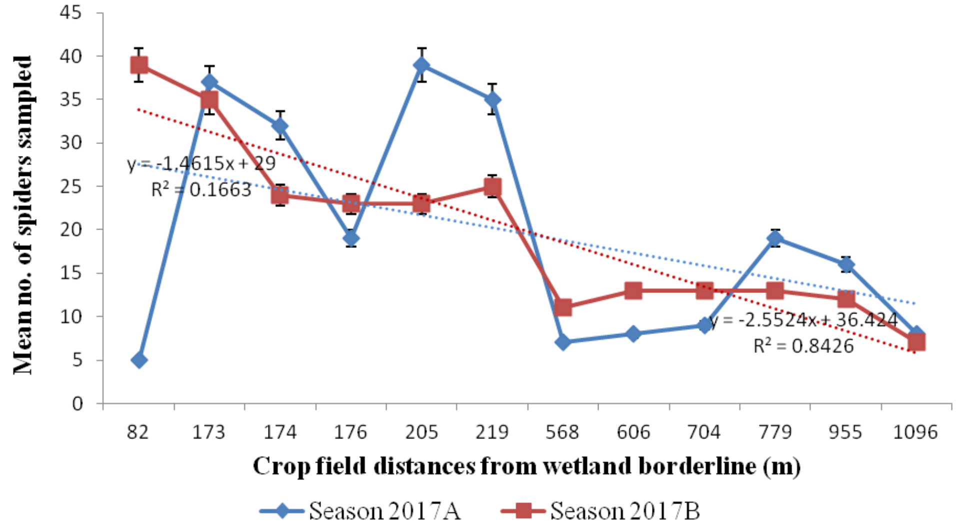

Fig. 3. Changes in predatory spiders populations per field sampled at different distances from the wetland borderline

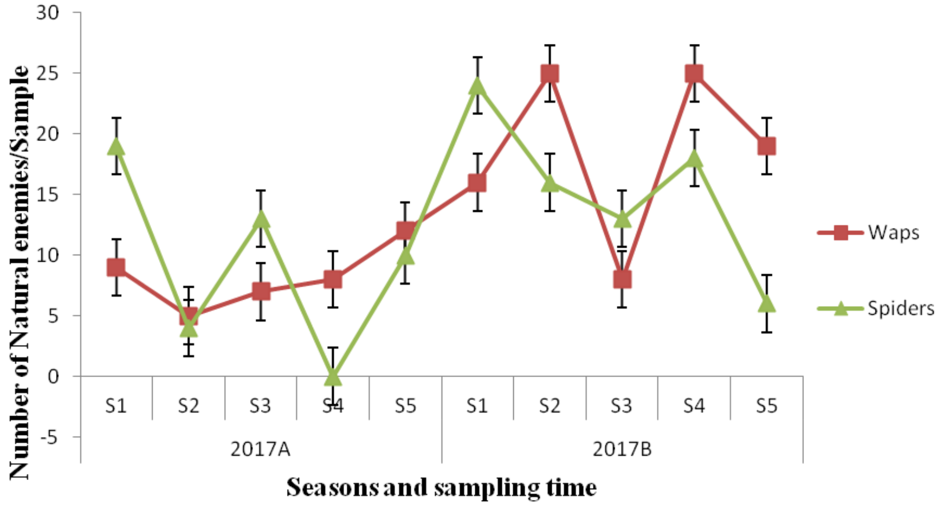

Fig. 4. Abundance of natural enemies at the wetlands borders for seasons 2017A and 201B

3.4 Discussion

The study has shown that significantly high populations of Hymenoptera parasiotid wasps and generalist predators (spiders) were recorded in fields closer to the wetland borders (82-219meters) while further increase in distance; 568-1096 meters from the wetland borders registered reduced natural enemies populations. This was observed in both seasons of the study, these findings relate to those of; Morandin et al. [19], Thomson and Hoffman [20] and Kruess and Tscharntke, [21] who found natural enemy abundance and parasitism rates reduce with increase in distance from woody field edges.

Similarly, to those of Nicholls et al. [22] who reported parasitism rates of natural enemies being high at the field edges than the middle of vineyards, and they suggested a limitation of dispersal distances from uncultivated area into crop fields being the cause of observed reduced parasitism.

The abundance of hymenopteran wasps in closer crop fields imply that these fields benefited from alternate hosts and food resources for adults parasitoids and moderate microclimate provided by wetland borders which increased wasps fecundity and longevity [23], therefore, proximate fields benefited from the spill over effect from the pool at wetland borders [24]. However, as time of sampling increased, it was observed that more Hymenoptera wasp population build up at the wetland borderline relatively increased as compared to the crop field. This indicates a migratory effect of wasps from areas of high disturbance to more stable sites such as those provided by wetland borders.

"Similarly the microclimate provided by wetland borders ensures high humidity that protects parasitoids from desiccation and thereby sustaining their feeding and host finding activities" [25]. "Similarly low temperatures have been reported to ensure parasitoid longevity for effective pest control in crops at smaller spatial scales from the adjoining non-crop habitats" [26,6]. These could as well explain why high abundance of hymenopteran wasps was observed in closer fields to wetland borders.

The abundance of generalist spiders in crop fields within 219 meters from the wetland borders seem to indicate that spiders were colonizing crop fields from the species pool provided by natural habitat [2]. This finding can be supported by similar reports by Sonja and Pfister [16] who found *T. montana* and *T. extensa* abundance increased in cereal fields from the field centres towards the hedgerows and riparian margins. And also, of Hogg and Danne [10] who found spider abundance and species composition high along transects that extended up to 250 meters from the oak woodland riparian. Therefore, closer crop fields benefited from the exportation effect of the wetland borders. The migratory tendency of spider can further be confirmed by the increasing reducing spider population at the wetland borderline as was observed that as sampling time increased, the spider populations was concomitantly decreasing at the wetland borderline while population of spiders at crop fields adjacent the wetland kept increasing. The findings from this study are in line with studies that have found crops adjacent to patches of natural habitats to have increased natural enemy populations [23,27,28,5].

Field edges influence Hymenopteran wasps and predatory spiders abundance and richness, thus directly affecting insect pest prevalence rates in the adjoining crop fields [29,30]. Although we have not attempted to quantify the effect of field edge types on Hymenoptera wasps and predatory spiders abundance, field edge type may influence Hymenoptera wasps and predatory spiders richness or diversity and abundance, in crop fields far away from the wetland borders, as the field margins potentially serve as conduits for insect pest natural enemies movements and transfer across multiple distances.

4. CONCLUSION

The findings from this study confirm that wetland borders are stable habitats that support more insect pest natural enemies build up. The higher populations in the stable habitats act as a source for agricultural fields at close proximity. However, these effects can be enhanced in crop fields distant from stable habitat through management of field margins. Also tracking bidirectional movement of parasitoids and predators at temporal scales is critical in employing practices within agroecosystems that promote preservation of Hymenoptera wasps and predators so as to sustain ecosystem services of pest management.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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