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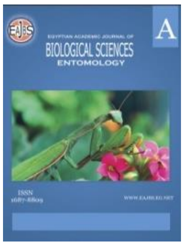

Effect of Spatial Distribution Pattern and Field Depth on The Population Dynamic of The Blister Beetle, *Meloe rugosus* M. (Coleoptera: Meloidae) Adults in Wheat fields in El-Bahariya Oasis, Western Desert, Egypt

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ABSTRACT

The blister beetle *Meloe rugosus* Marsham, was detected for the first time in El-Farafra oasis, New-Valley governorate-Egypt in 2018. Blister beetle causes significant damage to Wheat in El-Bahariya oasis. A survey was carried out during Wheat growing seasons 2018 and 2019 in Ain EL-Heiz locality (EL-Bahariya Oasis), to determine the spatial distribution of blister beetle adults in Wheat fields. Results based on the number of beetles showed that 3741 adults of *M. rugosus* were collected in 2018/2019. Day 35 (the 1st week of February) counted for the highest number of recorded beetles with (25.833 beetles) during 2018 however during the season but in 2019 the Day 28 (the 1st week of February) counted (24.33 beetles) in beetles count. North field site was the most preferred by beetles which contributed with more than 48% similarly, In season 2019 that North contributed with more than 50% of total beetles count. Thus, these results provide important insights into the preference of the blister beetles direction is the northeastern cardinal site of Wheatfield at the angle of 55º50´22" and 60º20´39" in the growing seasons 2018 and 2019, respectively. Beetles also exhibited different distribution patterns regarding their distribution at different levels of field depth. About 45 and 55 % of the total beetles' population distributed at one meter far from the field border, while only 4 m and 5 m distance showed no significant differences in beetles count. These spatial-temporal differences in distribution patterns are discussed in terms of adult behavior and prevailing agro-climate

INTRODUCTION

The role of spatial information in integrated pest management is well understood but the spatial relationships between insects and crop plants remain an aspect of pest/host-plant ecology which has received less attention. Moreover, it's needed for studies of insect movements into and within crops to promote the development of pest control strategies (Ferguson *et al*., 2003). Wheat (*T. aestivum* L.) is one of the most common field crops cultivated in El-Bahariya oasis and occupied the largest area of cultivated crops (52.7%), followed by alfalfa (47.04%), while peas occupied the smallest area (0.28%). However, these crops are threatened through growth season by many insect species, one of the most dangerous and common is the blister beetle, their adult greatly feeding on plant leaves, flowers and seeds causing considerable damage and crop loss (Ali *et al*., 2005; El-Sheikh and Tokhy, 2020). Blister beetles also known as oil beetles are a globally distributed beetle family with about 2,500 species in approximately 120 genera. In most of the taxa the first, very mobile larval instar is a triungulin larva that is responsible for the spreading and for finding the source of food (Lückmann and Assmann, 2006). Adult beetles are polyphagous, feeding especially on plants in the family's Amaranthaceae, Compositae, Leguminosae, and Solanaceae. Most adults eat only floral plants, first instar larvae (triungulins) frequenting flowers or clinging to adult bees, larval blister beetles are seldom seen (Selander, 1981).

The blister beetle, *M. rugosus* M. was first recorded as a pest of agricultural crops in El-Farafra oasis, New-Valley governorate, Egypt by El-Sheikh, 2020 and reported field observations on crop damage and food plants of adults. The serious problem of the presence of blister beetles attacking Grain, forage and legume crops does not restrict for crop damage and yield loss only but arises from their secretion, Cantharidin, a potent blistering agent and poisoning of livestock, particularly horses when feeding on alfalfa (Lucerne) contaminated with this fluid or dead blister beetles (Polettini *et al*., 1992).

The prevalence of the blister beetle adults as a serious pest of Wheat, faba bean and alfalfa in El-Bahariya locality is quite substantial and calls for effective management. The successful design of suitable management options will rely on the understanding of pest species distribution patterns and their response to the environmental gradient. In this study, we described the blister beetle distribution patterns based on its population abundance and distribution in the various cardinal sites and depth area of the Wheatfield in an attempt to improve our understanding of their ecology and management.

MATERIALS AND METHODS

Study Sites:

Field studies carried out in Ain EL-Heiz locality (EL-Bahariya Oasis, Western Egyptian Desert) Latitude: 28°32'59.99"N, Longitude: 29° 00' 60.00" E through 2018 and 2019 Wheat growing seasons. Three fields of Wheat were identified in each season and the area of the site was ≈ one acre. Wheat was planting using conventional tillage with cultivar SODS 12, planting date for each field was 30th November 2018 (field A ≈ 1.2 acre, field B ≈ 0.99 acre, field C ≈ 1.1 acre) and 25th November 2019 (field A ≈ 1.3 acre , field B ≈ 1.1 acre , field C ≈ 0.99 acre). No insecticide was applied on any of the wheat field. Fertilization rates were made according to recommendations.

Sampling:

a) Cardinal Distribution:

Three Wheat fields (area of 1 acre each) each randomly distributed were sampled. In each field, four sites of Wheat corresponding to the cardinal points (north, south, east, and west) were selected for the study. Each field was visited once weekly from crop emergence in each growing season. These visits were meant to capture only adults of the newly emerged blister beetle, *M. rugosus* (Coleoptera: Meloidae). In each visit, 400 randomly (100 per each direction) selected Wheat plants were checked for the presence of blister beetle adults (about 10 am.). Existing adults were counted in the spot, collected and recorded at weekly intervals according to Edward, 1990 and El-Sheikh, 2019.

The preference of beetles for a distinct cardinal site of the Wheatfield could be expected and estimated by the implementation of the following mathematically formula Mahmoud, 1981, and Hassan, 1998.

$$H = \sqrt{F1^2 + F2^2 + 2(F1.F2\ CosQ)}$$

Where:
H = powers summation.
F1 = the population in the north direction minus the population in the south direction, if the former is higher and the reverse is applied if the population in the south direction is higher.
F2 = the population on the east direction minus the population in the west direction, if the former is higher and is reversed if the latter is higher.
F1= N-S *F2= E-W*
Tan Q = Cosine of angle between the two directions.
Tan Q = F2/F1

b) Distance from The Field Border:

Similarly, to the former technique, the population density of newly emerged adults of *M. rugosus* was weekly estimated on Wheat during growth seasons. A wooden frame ($1m^2$) was prepared and used to count the number of beetles on Wheat / one square meter (approximately equal 100 plants) at different field depth, i.e. 1,2,3,4 and 5 meters far from the field border towards the center of the field. Samples were repeated four times for each field depth distance and continued from crop emergence until harvesting (Thomas and Vinod, 2009).

Data analysis:

The main effects and interactions were examined using ANOVAs (the corresponding multivariate tests had high power). Analysis of variance (ANOVA) applied using the Holm-sidak method to refuse the null hypnosis and confirm the presence of significant variance between different levels of factors. The probabilities of Epsilon corrected F values (Greenhouse-Geisser Epsilon) were calculated to compensate for deviations from univariate assumptions. The analysis becomes available using SigmaPlot V12.5 and MiniTab V18.1 software.

RESULTS

Regular survey and population estimation of the blister beetle, *M. rugosus* adults showed evidence of variation between patterns of adult distribution in different cardinal sites of Wheat fields as well as at different distance levels from the field border. 3741 adults of *M. rugosus* were collected in 2018/2019. Corresponding to an average of (414.75 beetles/1 acer) in 2018 and (520.5 beetles/1 acer) in 2019 (Table 1). Statistical analysis using Sidak pairwise method with 95% confidence showed that there were significant differences in beetles count during the experiment period. The results, as shown in Tables 2 and 3 indicate that in season 2018 Day 35 (the 1st week of February) counted for the highest number of recorded beetles with significant differences with other collection days (25.833 beetles, $P < 0.05$) except for day 42 (the 2nd week of February) (19.75 beetles) which show no significant differences with day 35 ($P > 0.05$). During season 2019 there were significant differences in beetles count during the experiment period. (Table 3), Day 28 (the 1st week of February) (24.33 beetles $P > 0.05$) counted for the highest number of recorded beetles with significant differences ($P > 0.05$) in beetles count with some of the collection days (0, 7, 56, 63, 70, 77, 84 and 91).

Cardinal Distribution Patterns:

Blister beetle infestation levels varied between cardinal sites (North, South, East, and West).The pie chart shows in 2018 (Table 1 and Fig. 1 A) that the North of the filed contributed with more than 48% (800 beetle) of total beetles count followed by East 32% (525 beetle) then South 13% (210 beetle) finally, West count for the lowest beetle's number with only 7% (124 beetle). In season 2019 From the chart (Fig. 1 B) it can be seen that North contributed with more than 50% (1038 beetle) of total beetles count followed by East 26%

(542 beetle) then South 17% (365 beetle) finally, West count for the lowest beetle’s number with only 7% (137 beetle). In season, 2018 there was a statistically significant interaction between Direction and dates of the collection ($P > 0.05$). On the other hand, season 2019 exposes the difference in the mean values among the different levels of Direction, and dates of the collection were greater than would be expected by chance after allowing for effects of differences in dates of collection and directions. There was a statistically significant difference ($P = <0.001$). Holm-Sidak statistical method revealed that data presented in (Table 4) showed in 2018 and 2019 revealed the significant difference between all direction stands. Data present in Figs. 2 A & B exposing the relationship between the beetle's count and the main four directions, which may reveal a connection between the four main directions and the beetle habitat.

From these results, the difference in the mean values among the different levels of Season 2018-2019, Direction, and dates of the collection is greater than would be expected by chance. There is a statistically significant difference ($P = 0.002$). To isolate which group (s) differ from the others use a multiple comparison procedure. There are significant differences ($P > 0.050$) between season 2018 and season 2019 in directions and beetles count. Together these results (Table 1) provide important insights into the preference of the blister beetles direction is the northeastern cardinal site of Wheatfield where the expected number of adults that could be occurred averaged 988.6 and 1075.5 beetles at the angle of 55º50´22" and 60º20´39" in the growing seasons 2018 and 2019, respectively.

Table 1: Adults expected at cardinal location preferred in wheat crop.

season	North	South	West	East	Total	Mean	F1	F2	Cos. Q	H	Site
2018	800a	210c	124d	525b	1659	404.75	590	401	0.99	988.6	55º50´22"
2019	1038a	365c	137d	542b	2082	520.5	673	405	0.99	1075.5	60º20´39"

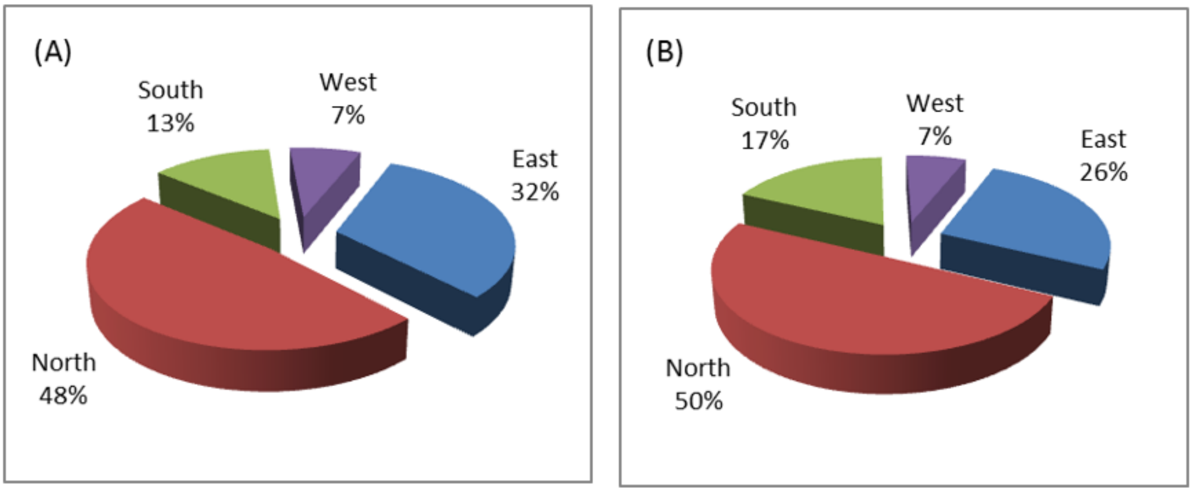

Fig. 1: The contribution of each direction with *M. rugosus* count session 2018 (A) /2019 (B) in wheat fields in El-Bahariya Oasis.

Table 2: Analysis of variance (ANOVA), using the Sidak method for experimental collection days of *M. rugosus* during 2018 in wheat fields in El-Bahariya Oasis.

Day	N	Mean	Grouping					
35	12	25.8333	A					
42	12	19.7500	A	B				
28	12	15.9167		B	C			
49	12	15.0000		B	C	D		
21	12	11.3333		B	C	D	E	
56	12	10.2500			C	D	E	
14	12	9.5000			C	D	E	F
63	12	7.1667			C	D	E	F
7	12	6.5833				D	E	F
70	12	5.3333					E	F
77	12	3.9167					E	F
0	12	3.8333					E	F
84	12	2.5833					E	F
98	12	0.6667						F
91	12	0.5833						F

Means that do not share a letter are significantly different.

Table 3: Analysis of variance (ANOVA), using the Sidak method for experimental collection days of *M. rugosus* during 2019 in wheat fields in El-Bahariya Oasis.

Day	N	Mean	Grouping						
28	12	24.3333	A						
35	12	21.4167	A	B					
42	12	18.7500	A	B	C				
21	12	17.8333	A	B	C	D			
49	12	15.3333	A	B	C	D	E		
14	12	14.9167	A	B	C	D	E		
7	12	12.5833		B	C	D	E	F	
56	12	12.2500		B	C	D	E	F	G
63	12	9.7500			C	D	E	F	G
0	12	8.6667			C	D	E	F	G
70	12	7.1667				D	E	F	G
77	12	5.8333					E	F	G
84	12	3.5833						F	G
91	12	1.0833							G

Means that do not share a letter are significantly different.

Table 4: Tow way analysis of variance (ANOVA), using the Sidak method for the count of *M. rugosus* in the four main directions during season 2018 and 2019 in wheat fields in El-Bahariya Oasis.

<table>
<tr><th rowspan="2">Comparison</th><th colspan="2">Diff of means</th><th colspan="2">t</th><th colspan="2">P</th><th colspan="2">P<0.050</th></tr>
<tr><th>2018</th><th>2019</th><th>2018</th><th>2019</th><th>2018</th><th>2019</th><th>2018</th><th>2019</th></tr>
<tr><td>North vs. West</td><td>15.022</td><td>21.452</td><td>15.715</td><td>11.951</td><td rowspan="5"><0.001</td><td rowspan="4"><0.001</td><td rowspan="6">Yes</td><td rowspan="6">Yes</td></tr>
<tr><td>North vs. South</td><td>13.111</td><td>16.024</td><td>13.715</td><td>8.927</td></tr>
<tr><td>East vs. West</td><td>8.911</td><td>11.810</td><td>9.322</td><td>6.579</td></tr>
<tr><td>East vs. South</td><td>7.000</td><td>9.643</td><td>7.323</td><td>5.372</td></tr>
<tr><td>North vs. East</td><td>6.111</td><td>5.429</td><td>6.393</td><td>3.024</td><td>0.006</td></tr>
<tr><td>South vs. West</td><td>1.911</td><td>4.214</td><td>1.999</td><td>2.348</td><td>0.048</td><td>0.021</td></tr>
</table>

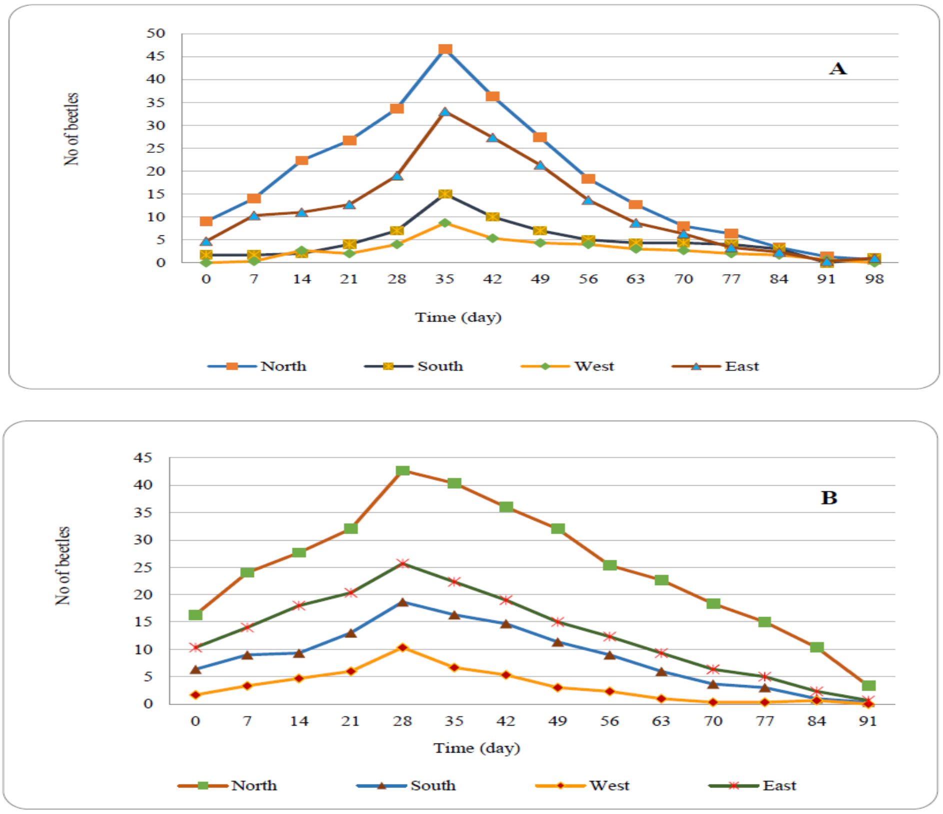

Figure 2: The number of *M. rugosus* in counteractions with direction of collection station in the filed during the experiment period session 2018 (A) /2019 (B) in wheat fields in El-Bahariya Oasis.

Distance from the Field Border:

Adults of the blister beetles differently distributed at various levels in Wheatfield depth. Results clarified that the beetle's activity was greatest and concentrated on Wheat plants located at one meter far from the field border. The chart (Figs. 3 and 4) showing the differences of beetles count with the distance from the border of the filed. Revealing that, the more distance from the filed border the lowest opportunity to count more beetles with 54 % (192 adult) recorder from only 1 m distance in 2018 and 55 % (176 adult) recorder from only 1 m distance in 2019. Adult density diminished as the distance of plants increased towards the field center. Blister beetles infestation levels varied between levels of the field depth the lowest level (10 and 14 adults) on plants 4 m in 2018/2019 respectively, far from the field border. Infestation levels at 2 and 3 m were intermediate with (101 and 32) in 2018/2019 respectively. While only (6-7 adults), could be detected, on plants 5 m far from the field border 2018/2019 respectively.

The effect of different levels of Distance from the filed border depends on what level of date of collection is present. There is a statistically significant interaction between Distance from filed border and date of collection (Table 5 and Fig 4). In both 2018/2019 ($P = <0.001$). In the same manner, there were significant differences ($P > 0.050$) between distance from the filed border and the beetles count. In 2018, Only 4 m and 5 m distance showed no significant differences in beetles count. Instead of 2019, only (4 m Vs 5 m) and (3 m Vs 4 m) distance showed no significant differences in beetles count. There are no significant differences ($P < 0.050$) between season 2018 and season 2019 in the role of distance from filed border and beetles count, revealing that the beetle's habitat somewhat related to the filed boarder.

Table 5: Tow way analysis of variance (ANOVA), using the Sidak method for the count of *M. rugosus* in different distance from studied filed border during season 2018 and 2019 in wheat fields in El-Bahariya Oasis.

<table>
<tr><th rowspan="2">Comparison</th><th colspan="2">Diff of means</th><th colspan="2">t</th><th colspan="2">P</th><th colspan="2">P<0.050</th></tr>
<tr><th>2018</th><th>2019</th><th>2018</th><th>2019</th><th>2018</th><th>2019</th><th>2018</th><th>2019</th></tr>
<tr><td>1.000 vs. 5.000</td><td>4.133</td><td>4.024</td><td>16.757</td><td>18.439</td><td rowspan="7"><0.001</td><td rowspan="7"><0.001</td><td rowspan="9">Yes</td><td rowspan="8">Yes</td></tr>
<tr><td>1.000 vs. 4.000</td><td>4.044</td><td>3.857</td><td>16.397</td><td>17.676</td></tr>
<tr><td>1.000 vs. 3.000</td><td>3.333</td><td>3.429</td><td>13.514</td><td>15.712</td></tr>
<tr><td>2.000 vs. 5.000</td><td>2.111</td><td>2.071</td><td>8.559</td><td>9.492</td></tr>
<tr><td>2.000 vs. 4.000</td><td>2.022</td><td>1.952</td><td>8.199</td><td>8.947</td></tr>
<tr><td>1.000 vs. 2.000</td><td>2.022</td><td>1.786</td><td>8.199</td><td>8.183</td></tr>
<tr><td>2.000 vs. 3.000</td><td>1.311</td><td>1.357</td><td>5.316</td><td>6.219</td></tr>
<tr><td>3.000 vs. 5.000</td><td>0.0800</td><td>0.585</td><td>3.243</td><td>2.728</td><td>0.004</td><td>0.021</td></tr>
<tr><td>3.000 vs. 4.000</td><td>0.711</td><td>0.429</td><td>2.883</td><td>1.964</td><td>0.009</td><td>0.100</td><td>No</td></tr>
<tr><td>4.000 vs. 5.000</td><td>0.0889</td><td>0.167</td><td>0.360</td><td>0.764</td><td>0.719</td><td>0.446</td><td>No</td><td>No</td></tr>
</table>

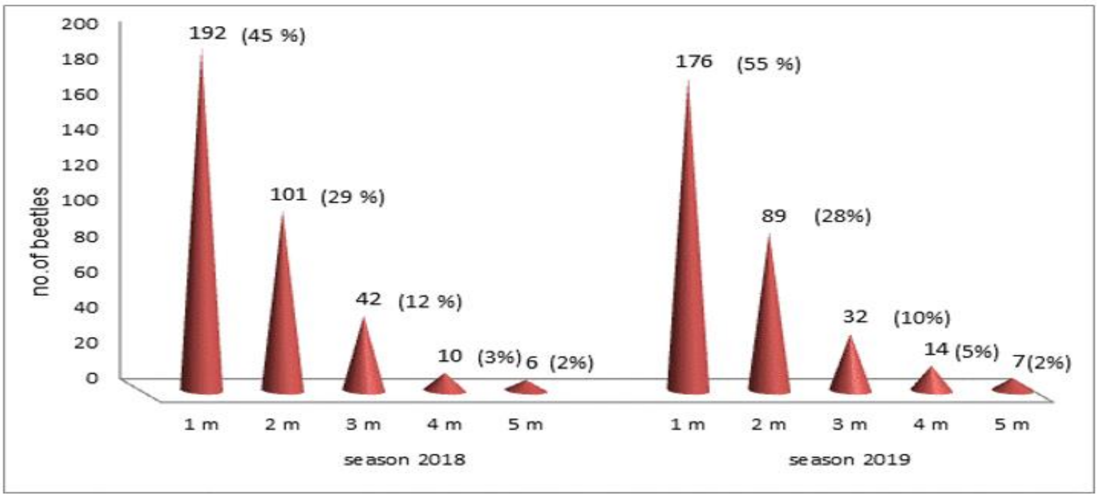

Fig. 3: The percentage contribution of *M. rugosus* in different distance from studied field border during season 2018 /2019 in wheat fields in El-Bahariya Oasis.

Fig. 4: The *M. rugosus* feeding on wheat, (*T. aestivum* L.) crop in El-Bahariya Oasis, Western Desert, Egypt.

DISCUSSION

The present study aimed at understanding the distribution patterns of the blister beetle, *M. rugosus* adults in Wheat fields at EL-Bahariya oasis, Western Egyptian Desert. Results revealed that cardinal north followed by the east field sites are the greatest infested portions by the blister beetle adults where the highest adult population usually occurs. This means that the north-east cardinal direction was the most preferred distribution of adults. The preference of this species to a specific cardinal direction could be ascribed to variation in agro-climate. North site is cooler than others which favor distribution activity of adults. (El-Sheikh and Tokhy, 2020) explained Immediately after the emergence of *M. proscarabaeus* adults, beetles were seen moving in swarms from the rangeland to Wheat fields where they disperse and starting feeding for a period of up to 150 days. Wheat was seeded in early December and beetles emergence time convened with arising of Wheat seedling of about 10-12 days with 2-3 leaflets these young plants are the most preferable food.(Ali *et al*., 2005) reported 11.9- 26.9˚C (av. 19.4˚C) is the favorable temperature range for the adult activity of blister beetle. Temperature prevailing in south and west cardinal sites is higher which opposes insect activity. (El-Sayed *et al*., 1978) gave a similar explanation concerning trapping of a high number of aphids (*Aphis craccivora*) in the north direction, (Saafan, 1986) on *Ceratitis capitata* where the north-eastern site was the most preferred flight direction. These results correspond to (Dietmar *et al.*, 2009) when explaining the distribution patterns of herbivorous insects and the extent of the impact of space and time on them, where it proved that the direction of the prevailing northwest wind played an important role by 72% in the distribution of insect density. Adults of blister beetle, *M. rugosus* was recorded as insect pest feeding on leaves and flowers of Wheat, faba bean, peas, alfalfa, Egyptian clover, onion, and the wild weed *Meliolotus indica*, (El-Sheikh, 2020).

Similarly, distribution of adults with the highest level on Wheat plants at one meter far from the field border ascertain our view that adult distribution of blister beetle is not only controlled by food abundance but also by the microclimate of plants, they feed on. Temperature nearly the field border was lower than that measured at the inner field, so beetles prefer low-temperature range particularly if fall and winter were considered as the main feeding times. Furthermore, observed decrement in the number of distributed beetles as increasing the distance from the field border could be assumed to dilution of beetles population and intra-specific competition of individuals on the viable food particularly at the beginning of their dispersion from aestivating sites (Kineney *et al*., 1998; Ward, 1985). The pattern of cardinal spread of blister beetle adults in the field may provide good information about the native any system of beetles activity in the field, so control measures should be applied and concentrated in northeast direction and on a strip field border of 1-3 m depth toward the inner field and not overall field treatment. Such an application should give successful management saving money, effect, and time.

Acknowledgements

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ARABIC SUMMARY

تأثير نمط التوزيع المكاني وعمق الحقل على ديناميكية تعداد الخنفساء الحارقة *Meloe rugosus* M (Coleoptera: Meloidae) ، في حقول القمح بواحة البحرية ، الصحراء الغربية ، مصر

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سجلت الخنفساء الحارقة *Meloe rugosus* Marsham لأول مرة في واحة الفرافرة بمحافظة الوادي الجديد - مصر عام 2018. تُسبب الخنفساء الحارقة أضرار كبيرة لمحصول القمح في الوحات البحرية. أجري حصر لتعداد الخنافس الحارقة في حقول القمح خلال موسمي 2018 و٢٠١٩ بمنطقة عين الحيز (الواحات البحرية) لتحديد التوزيع المكاني. أثبتت النتائج المستندة إلى عدد الخنافس انه تم حصر 3741 فرد بالغ من *M. rugosus* في 2019/2018، تم تسجيل اكبر عدد من الخنافس (25.833 خنفساء) في اليوم الخامس و الثلاثين من بداية الحصر (الأسبوع الأول من فبراير) عام 2018 وخلال موسم 2019 سجل في اليوم الثامن و العشرون (الأسبوع الأول من فبراير) حوالي (24.33 خنفساء). اثبتت النتائج ان اتجاه الشمال هو الأكثر تفضيلاً وملاءمة من قبل الخنافس بنسبة 48 % و٥٥٪ من إجمالي عدد الخنافس خلال عامي الدراسة 2019/2018. وبذلك، توفر هذه النتائج رؤى مهمة حول تفضيل الاتجاه للخنافس الحارقة وهو الاتجاه الشمالي الشرقي لحقل القمح بزاوية ٥٥"22´50º و٦٠ "39´20ºخلال موسمي الدراسة 2019/2018 على التوالي. واثبتت الدراسة أيضًا أنماط توزيع مختلفة للخنافس، فيما يتعلق بتوزيعها على مستويات مختلفة من عمق الحقل بشكل عام، حيث بلغ حوالي 45% و55 % من إجمالي عدد الخنافس على مسافة واحد متر من الحدود الميدانية خلال عامي الدراسة، في حين لم تُظهر مسافة 4 و5 متر أي اختلافات كبيرة في عدد الخنافس. تم مناقشة الاختلافات المكانية والزمانية من حيث أنماط التوزيع وسلوك جمهور الخنافس والمناخ الزراعي السائد.