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Cereals losses in the Algerian Saharan region: Insights into the contribution of *Messor foreli* (Santschi, 1923)

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Abstract:The cultivation of wheat is a relatively new agricultural endeavor in the Algerian Saharan. The Algerian government has recently prioritized this initiative as part of its broader strategy to enhance food security and reduce dependence on cereal imports. However, this new speculation, grown under a pivot, is often impacted by various environmental (extreme temperatures, aridity, low soil fertility) and biological factors(pests). One of the key contributors to cereal losses in this region is the harvester ant species *Messor foreli* (Santschi, 1923).The estimate of overall losses, especially the impact of *M. foreli* on cereal crops, concerned four pivots spread over two stations in Ouargla region (southeast of Algeria). This study proved that *M. foreli* ant nests could occupy about 0.009% of the total cultivated area, to be 139 to 519 ant nests in each pivot. However, the rate of production overall losses has been estimated between 8.66% and 17.65% with *M. foreli*'s contribution that has fluctuated between 1.93 and 2.43 qx/pivot from a whole mean potential production that ranged between 260 g/m^2 on *Triticum aestivum* and 408.01 g/m^2 on *T. durum*. Outputs showed a negligible *M. foreli* effect compared to other weight losses, which ranged from 75.98 to 163.47 qx/pivot.

Key words: Effect, Estimation, Cereals pivots, Ant nests, *Messor foreli* (Santschi, 1923), Algerian Saharan.

1 INTRODUCTION

Algeria's agricultural system places a high value on cereals, with production reaching 5 million qx in 2019 (FAOSTAT, 2021). Their significance was strongly explained by the evolution of sown areas, of which durum wheat and barley account for 74% of total cultivated soil (MADR, 2021). The southern regions of the country have large irrigated areas intended for this crop nearly 3542 ha have been harvested in Ouargla region during the 2017-2018 campaign (MADR, 2021).

Nowadays, cereals face a multitude of problems. In addition to the socio-economic problems, those caused by severe water stress as well as other vegetative accidents (scalding and floral organ degeneration), attacks due to parasites, the pullulating of certain predatory animal species, and the appearance of new pests constitute one of the main causes of yield reduction and deterioration (Cissokho et al., 2015; Richi et al., 2019; Ladoui et al., 2020).

Ants, especially the genus *Messor* (Formicidae, Myrmicinae), represent one of the classic pests of cereal crops (Cerdan, 1989). *Messor* spp. consists of approximately 120 granivorous species with 42 described subspecies. All of them are of medium size and dominate deserts, dry meadows, semi-arid zones, and savannas (Collingwood, 1985; Plowes et al., 2013; Bolton, 2019).

They have attracted the attention of several scientific researches due to their abundance, availability, and high potential to damage crops. Losses can reach 90% of harvested seeds for the most abundant plant species (Inouye et al., 1980; Beattie, 1989). Furthermore, one-third of the harvested grains in Algeria's highlands could end up in ant lairs. In North Africa, *Messor foreli* Santschi (1923), mainly granivorous in Mediterranean meadows (Lopez et al., 1993; Cerda & Retana, 1994), causes losses ranging from 50 to 100 kg/ha on wheat (Jolivet, 1986). In light of this, the current study focuses on the significance of *M. foreli*'s losses on the pivot irrigation of cereals in Ouargla, Algeria's northern Sahara. Up to 50,000 seeds can be carried daily in an ant nest(Detrain & Tasse 2000 ; Arnan et al. 2010). *Messor barbarus* could be responsible for high losses of weed seeds in dryland (Baraibar et al., 2011a ; Torra et al., 2016; Merienne et al., 2021).

Previous studies have highlighted the impact of *Messor* on cereal production in the Algerian Saharan region, but the extent of the losses and the specific mechanisms by which the ants contribute to these losses are not fully understood. This study aims to provide deeper insights into the relationship between *Messor foreli* and cereal losses, with the goal of informing potential mitigation strategies and improving the overall productivity of cereal cultivation in the region.

2 MATERIALS AND METHODS

2.1. Study area

This work focuses on Ouargla region (29° 13' to 33° 42' N.; 3° 06’ to 5° 20’ E.), which is located at 800 km to the southeast of the capital Algiers. It was characterized by a dry period over the whole year (2000 to 2020) and belongs to the Saharan bioclimatic stage with a mild winter. The region was affected by a difficult environment due to, an intense luminosity, a strong evaporation and large amounts of energy. thermals. The soil has a sandy and coarse texture that is moderately alkaline.

Within this region, two stations have been chosen for study, namely Remtha and ERIAD farm of Agro-Sud in Hassi Ben Abdellah (HBA). In both stations, two cereal crops pivots have been selected.

2.1.1. Station 1 (Remtha)

It is an agricultural area (31°56’59’’ N; 4°47’17’ E) that was located 16 km west of Ouargla city, on 50 m of altitude. It was created in 2015 with a total area of 200 ha. It contains six durum wheat crops pivots (*Triticum durum* Linnaeus, 1753), with an area of 30ha for each. A preventive treatment with a fungicide has been carried out from October 2017 until April 2018. Herein, two crops have been selected (Tab. 1).

2.1.2. Station 2 (Hassi Ben Abdallah : HBA)

This farm (32° 02' 03" N; 5° 30' 52" E) has been created in 1991 and was located 31 km to the northeast of Ouargla city, on 152 m of altitude. It covers a total area of 1675 ha, of which 488 ha have been cultivated. Overall, it was specialized in cereals, with 17 pivots of 30 ha each. It also has a 10ha palm grove with 1400 date palms (*Phaenix dactylifera* Linnaeus, 1753). Herein, two different cereal crops pivots (*T.aestivum* Linnaeus, 1753 and *Hordeum vulgare* Linnaeus, 1753) of 30 ha have been selected (Tab. 1) for 2012 and 2015. It should be mentioned that each pivot contains five wheels spaced at 60 m (6 spans).

Table. 1. Features of cereal crops according to stations in southern Algeria

Station	Pivot	Surface	Culture	Variety	Seed rate (qx/ha)

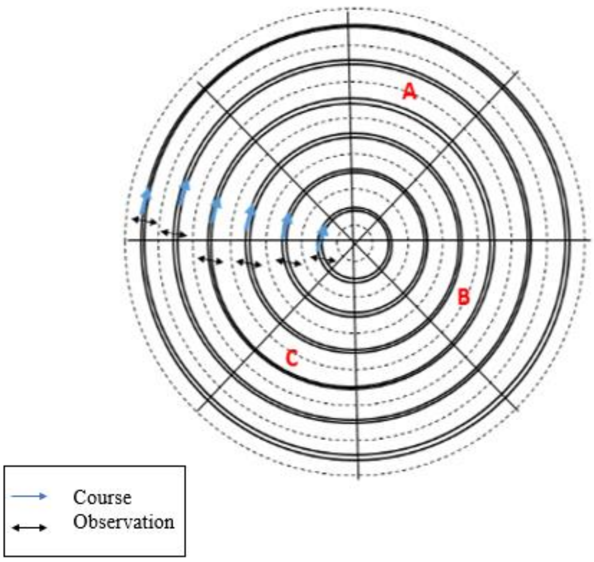
		(ha)			
Remtha	Pivot 1	30	*Triticum durum*	Vitron	2
	Pivot 2	30	*Triticum durum*	Vitron	2
HBA	Pivot 3	30	*Triticum aestivum*	Maouna	2.5
	Pivot 4	30	*Hordeum vulgare*	Saida	1.5

2.2. Methodology

The current study covered the estimation of ants' damages on cereal pivot. The work has been carried out over several steps.

2.2.1. Estimation of soil occupation rate (%) by ant nests

This step has been performed via four outputs for each sole, namely, during the seeding period, after emergence, pruning and the last during the filling and maturity of the grains. First, each sole at the pivot has been subdivided into 8 portions, 3 have been selected to scan the empty ranges (n) and calculate the average number of ant nests within each portion (Fig. 1).



A, B and C = sampled surface.

Fig. 1: Representative schema of adopted samplingon field

Ant nests present on parcels have been considered bare soil (crop totally absent; Fig. 2). The diameters of ant nests have been estimated in order to calculate their surfaces.

Thus, the occupied area by ant nests (TOF%) has been estimated as follows:

2.2.2. Mean area of ant nests

During the passages around the spans of each pivot, ant nests have been simulated as circles with a measured diameter (Xi) (Fig. 2).

$$Sf = (\pi * r^2)$$

Sf = area occupied by ant nest.

π = 3.14;

r^2 = radius of ant nests, Xi/2.

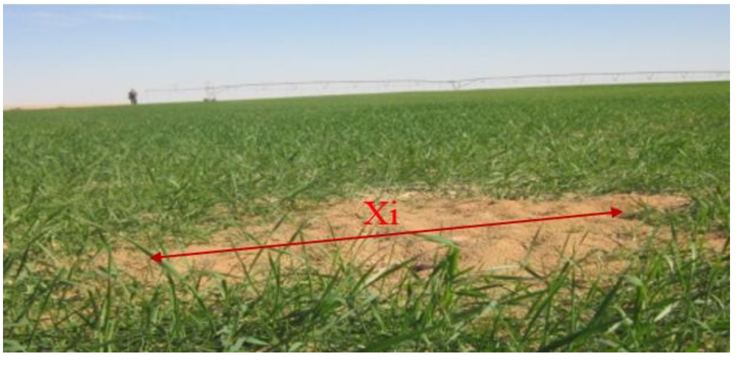


Fig. 2: Large diameter of ant nests (Xi)

In order to estimate the mean area of ant nests, the root mean of square (MQ) method has been used to calculate the mean diameter given by the following formula (Scherrer, 1984):

$$MQ = \sqrt[2]{\frac{\sum Xi^2}{n}}$$

MQ: mean of square diameter;

Xi: measured diameter of ant nests;

n: total number of ant nests for each pivot.

The mean area (Smf) has been deducted corresponding to:

$$Smf = (MQ/2)^2 * \pi$$

$(MQ/2)^2$: mean radius of ant nests.

After calculating the mean area, the estimation of the total area (St) occupied by ants at each pivot has been as follows:

$$St = Smf * n$$

n: total number of ant nests for each pivot;

St: total area occupied by ant nests.

2.2.3. Rate of soil coverage (%) by ant nests

It corresponds to the total area occupied by ant nests compared to the surface of pivot.

$$TOF\% = \frac{St}{Sp} * 100$$

TOF%: rate of soil occupied by ant nests;

Sp: total area of pivot;

St: total area occupied by ant nests.

2.2.4. Estimation of yield

The yield has been evaluated in two ways: the potential yield and the real one given by the actual farmer. The latter is given per hectare after harvest by dividing the overall yield (qx/30ha) by the number of hectares (30ha).

2.2.5. Estimation of potential yield (Rdt.P)

It was calculated following the manual harvest three times on $1m^2$ realized for each pivot. The harvest of each surface has been transferred into a paper bag in order to estimate later the mean yield per m^2. Harvesting points have been located in areas that were unharmed by phytosanitary problems and were far away from boundaries (avoiding the border effect).

The mowed ears have been brought back to the laboratory to be delicately scraped and weighed. Thus, the production from each sampling point ($1m^2$) and then the mean production per $1m^2$ have been determined. By extrapolating of mean production per $1m^2$, real yield has been estimated without the presence of ant nests in cereals pivots as follows:

2.2.6. Real yield obtained by the farmer (Rtd.R)

It was obtained per hectare by the farmer after the total harvest at cereals pivot. It agrees to:

$$Rdt.R(qx/\ ha) = \frac{total\ harvested\ \ production \text{ at cereals pivot(qx)}}{pivot\ area\ (ha)}$$

2.2.7. Methods of estimating losses

This step suggests a few necessary elements: potential yield (Rdt.P), real yield (Rdt.R), and the rate of soil coverage by ant nests (TOF).

2.2.8. Estimation of total losses

$$Ptp = Rdt.P - Rdt.R$$

Ptp: total weight losses (qx/ha);

Rdt. P: potential yield (qx/ha);

Rdt. R: real yield obtained by the farmer (qx/ha).

2.2.9. Estimation of losses due to the ant nests location at cereals pivot

$$Ppf = \frac{Rdt.P\ * St}{Stp}$$

Ppf: weight losses (qx) due to the ant nests compared to the cereal pivot;

St: total area (m²) occupied by ant nests at cereals pivot;

Stp: cereals pivot surface = 30ha.

2.3. Statistical Analyses

For statistical analyses, data inputs have been processed using R software (R3.4.1), especially the ggstatsplot package (PANTIL, 2021).We used a test for comparison of means, Welch's Anova, justified by the inequalities of variance (heteroskedasticity). For post-hoc tests, Games-Howell test was used to perform multiple comparisons between group means.

3 RESULTS AND DISCUSSION

3.1. Estimation of cereal in southern Algeria

The production has been estimated first according to the potential yield calculated before harvest using unharmed areas (maximum yield) then according to the real yield obtained by the farmer after harvest.

Depending on the pivots, yield recorded pivot 2 had the highest mean value with 441.2 ±106.4g/m^2, or 44.1± 10.6qx/ha, while this of pivot 3 had the lowest values with 260 ±30g/m^2 (Fig. 3).

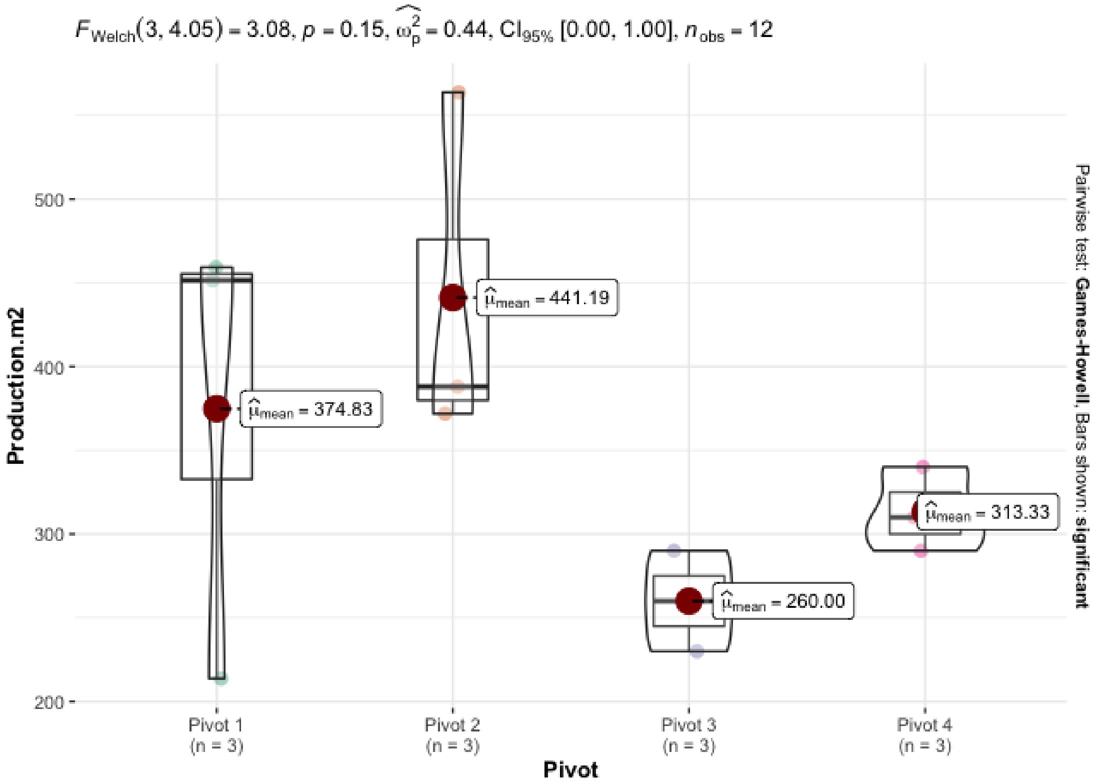


Fig. 3: Production of cereal crops at cereals pivot

Depending on crop varieties, *Triticum durum* ensured the highest potential mean yield (408.01±116.8g/ m^2), unlike *T. aestivum*, which had the lowest value (260±30g/ m^2; Fig. 4).

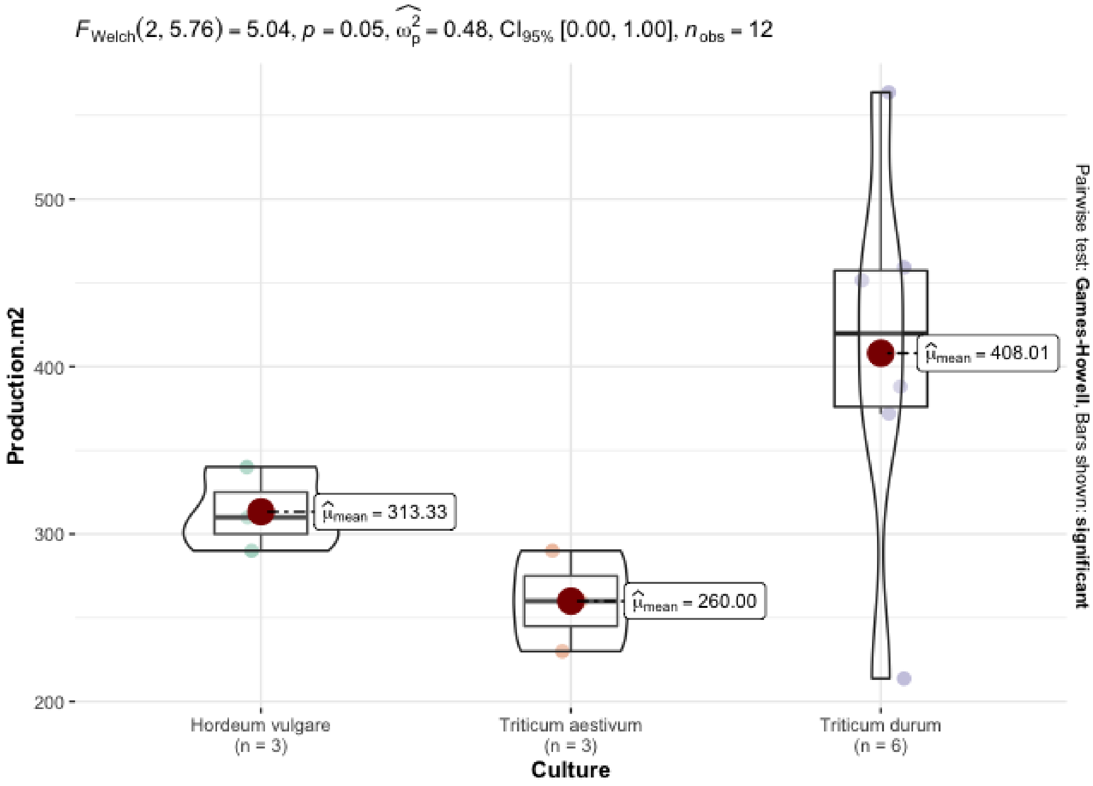


Fig. 4: Production of cereal crops according to varieties

3.2. Estimation of cereal production losses at cereals pivot in southern Algeria

Depending on the pivot sites, the mean diameter of the ant nests varied between 1.30m (Pivot 3) and 1.91m (Pivot 2 ; Fig. 5). The highest range of variation has been advanced under pivot 1 (min = 0.55m; max = 5.97m), while the lowest has been noted in pivot 3. Results showed a significant statistical difference between ant nests at cereals pivots (p = 7.06 e-04), especially between pivots 2 and 3 (p = 0.02).

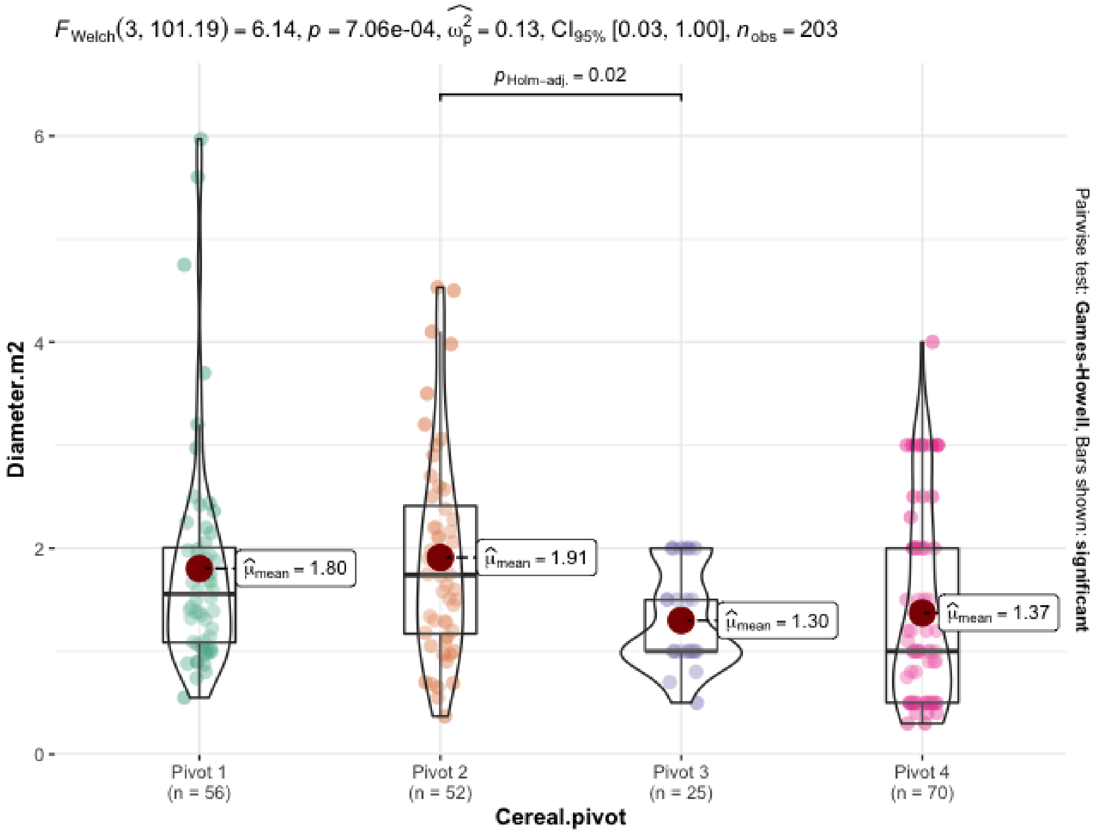


Fig. 5: Distribution of ant nests diameters according to pivot sites

Depending on the culture (Fig. 6), the mean diameters of ant nests varied considerably from one crop to another (p = 2.56e-4) between 0.30 (*T. aestivum*) and 1.85m (*T. durum*). Pairwise comparisons confirmed significant differences between both species (p = 1.13-4) and between *T. durum* and *H. vulgare* (p = 9.20 e-3), mentioning that the diameters of ant nests within *T. aestivum* and *H. vulgare* belonged to the same group.

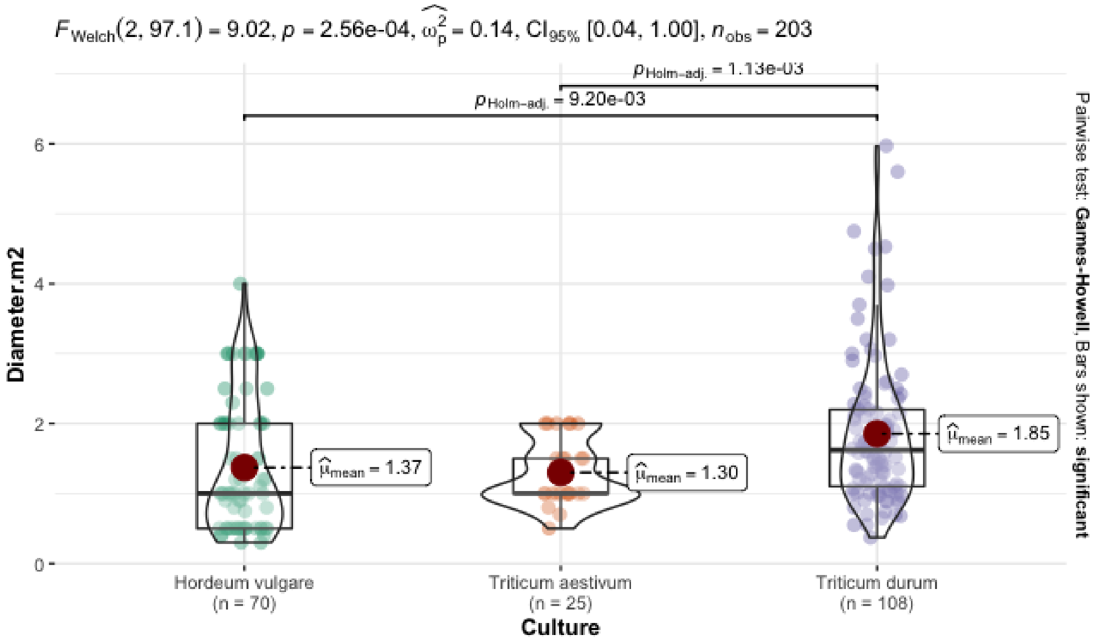


Fig. 6: Distribution of ant nests diameters according to cereal species

The results of soil coverage rates at cereals pivot have been listed on Table 2.

Table 2. Rates (%) of soil covered by *Messor foreli* ant nests on different cereals pivots in different stations

	Remtha		**Hassi Ben Abdallah**	
	Pivot 1 (*T. durum*)	**Pivot 2 (*T. durum*)**	**Pivot 3 (*T. aestivum*)**	**Pivot 4 (*H. vulgare*)**
MQ	2.1	2.16	1.38	1.66
Smf	3.46	3.65	1.5	2.16
NFP	19	17	65	45
N	149	139	519	360
St(m²/Portion)	64.59	63.29	97.03	96.99
Portion surface (ha)	3.75			
St(m²/ha)	17.225	16.877	25.874	25.864
TOF%	0.00574	0.00563	0.00863	0.00862
St(m²/30ha)	516.743	506.316	776.207	775.909

St(ha/30ha)	0.05156	0.05063	0.07762	0.07759

MQ: root mean square (m²); Smf: mean area of ant nests (m²); NFP: number of ant nests per portion; n: total number of ant nests; St(m²/Portion): total area of ant nests per portion (m²); SP: area of portion (ha); St: total ant nests area (m² and ha); TOF: rate of soil occupied by ant nests.

For the real yields obtained by farmers after harvest, they are low in pivot 3 = 23.4qx/ha and high within pivot 2 = 40.3qx/ha (Tab. 2).

In addition, the number of empty ranges due to the location of ant nests varied from pivot to another with valued of 139 and 519 (291.8±182.6; Tab. 2). Ant nests occupied a total area (St) that varied between 506,316 and 776,207 m². This reproduced soil occupation rates of up to 0.009% of the total crop area (30 ha). The root mean square further of ant nests ranged between 1.38 and 2.16 m², whereas the area of a single ant nests could reach 3.65 m².

Tab 3: Yield and yield losses due to ants on cereal pivots within two stations

	Remtha		**Hassi Ben Abdallah**	
	Pivot 1 (***T. durum***)	**Pivot 2** (***T. durum***)	**Pivot 3** (***T. aestivum***)	**Pivot 1** (***T. durum***)
Rdt. P (qx/ha)	37.48±13.96	44.12±10.64	26±3	31.33±2.52
Rdt. R (qx/ha)	32.7	40.3	23.4	25.8
Ptp (qx)	143.4	114.6	78	165.9
TPtp (%)	12.75	8.66	10	17.65
Ppf (qx/pivot)	1.93	2.24	2.02	2.43
Ap (qx/pivot)	141.47	112.36	75.98	163.47
Tpf (%)	0.004	0.0049	0.0111	0.0052

Rdt. P: potential yield; Rdt.R: real yield; Ptp: total weight losses (qx); TPtp: rate of total losses compared to area under pivot; Ppf: losses of weight (g and qx) due to ants compared to the pivot area; Ap: other losses (qx); Tpf: rate of losses due to ants compared to the pivot area.

The yield potential of each cereal crop varied between 26 qx/ha obtained in pivot 3 and 44.12 qx/ha estimated in pivot 2 (Tab. 3). On the other hand, the yield actually given by the farmer has been comparatively low: 23.4 qx/ha (pivot 3) up to 40.3 qx/ha (pivot 2). Barley cultivated in pivot 4 showed very high total production losses of 165.9 qx/30ha (Tab. 3), followed by durum wheat losses of 143.4 (pivot 1) and 114.6 qx (pivot 2). However, total production losses on common wheat have been almost insignificant (78 qx/30ha). All reported values have recorded a rate of total losses between 8.66 (pivot 2) and 17.65% (pivot 4) of the total crop area, with ant participation estimated to be 1.93qx (pivot 1) and 2.43qx (pivot 4). However, the proportional losses were due to the installation of ants on the total cultivated area, which were estimated between 0.004% (pivot 1) and 0.01% (pivot 4). While some weight losses ranged from 75.98 to 163.47qx/pivot.

3.3. Discussion

The highest potential yield has been estimated with *T. durum* culture at 408g/m^2 (seeding dose = 2qx/ha), while *T. aestivum* had the lowest value to be 260 g/m^2 (seeding dose = 2.5qx/ha). Obtained results were probably due to the dissimilarity of varieties, dose and seeding date (Amokraneet al., 2002). The number of *M. foreli* ant nests present in each pivot varied between 139 and 519 nests, accordingly, observations of Baraibar et al. (2011b) have been confirmed because they have showed populations of *M. barbarus* could reach a mean density of 468 nests/ha on cereals in a semi-arid region. In the Mediterranean region, the average number of nests /ha might approach 200 (Detrain & Tasse 2000; Arnan et al. 2010).Ninety *Messor barbarus* ant nests, are presentin three 50*50 m subzones in Spain's cereals(Torra et al., 2016). On the other hand, the number of *M. galla* ant nests have been poorly recorded in Bandia Forest (Senegal), varying according to time and space between 0.25 and 1.3 active nests/ha (Gillon et al., 1984). It is appropriate to mention also the age of the parcels, which could influence the presence and density of ant nests. In the current study, soles under pivots 1 and 2 have been exploited for 4 years, while those in pivots 3 and 4 were older (more than 20 years), which explained the ants' upkeep and high densities in the last two pivots compared to others. Some species of the genus *Messor* prefer open and sunny environments with very dense vegetation (Blatrix et al., 2016). While others as the case of *M. capitatus* have favor to sites with ancient anthropogenic activity, or maintained soils without expansion appearance (Lebas, 2021). Moreover, ant nests have occupied up to 0.009% of the total cultivated area, which has been the highest rate. This is due both to crop maintenance and irrigation system (pivot spraying). For total production losses, values vary between 8.66 (pivot 2) and 17.65% (pivot 4) of the total crop area. The contribution of *M. foreli* appears minor, fluctuating between 0.004% (1.93qx in pivot 1) and 0.01% (2.43qx in pivot 4), thus reflecting a negligible effect on production compared to other weight losses ranging from 75.98 to 163.47 qx/pivot. Losses have been due especially to the empty ranges occupied by *M. foreli* ant nests, without taking into account the direct losses on ears and seed stock within the nests. Therefore, this result was much lower than that obtained by Gillon et al. (1984), who have stated that, on the production and feeding of seeds, *M. galla* have reduced the production by 0.4-2%, adding to that the effect of two other granivorous groups, rodents (1-15%) and birds (6-26%) around the Sahelo-Sudanese environment (Senegal). *M. barbarous* caused grain yield losses that were estimated to 0.6 and 9% of the potential yield. Yield losses significantly increased with increasing nest density, nest size and with number of years of no-till (Baraibar et al., 2011b). These harvester ants can take 46–100% of freshly generated seeds, depending on the variety of plant (Westerman et al., 2012). Similar observations have been noted in the American and Australian desert areas where rodents and ants were the major seed pests (Brown et al., 1979; Ludwig and Whitford 1981; Wagner & Graetz, 1981).

4 CONCLUSIONS

The Saharan areas of Algeria were constantly noticed for their high cereal production potential given their large agricultural areas, water reserves, and pedo-climatic conditions that meet particularly the requirements of cereal cultures. However, the presence of pests has a detrimental effect on yields, and ants are one of the main enemies. *M. foreli* ant nests occupy agricultural areas and cause minor losses, but probably more damages to consumed and stored seeds inside ant nests, which ensures their maintenance under the pivots, especially in these desert areas with low food resources.

5 REFERENCES

Amokrane, A., Bouzerzour, H., Benmahammed, A., Djekoun, A. & Mekhlouf, A. (2002). Étude comparative des variétés de blé dur (*Triticum durum* Desf.) d'origine algérienne, Syrienne et Européenne sous climat de type Méditerranéen. *Sciences & Technologie C, Biotechnologies*, 33-38.

Arnan, X., Retana, J., Rodrigo, A., & Cerdá, X. (2010). Foraging behaviour of harvesting ants determines seed removal and dispersal. *Insectes sociaux*, *57*, 421-430.Baraibar, B., Torra, J.& Westerman, P.R.(2011b).Harvester ant (*Messor barbarous* (L.)) density as related to soil properties, topography and management in semi-arid cereals. *Applied Soil Ecology, 51*, 60–65.

Baraibar, B., Ledesma, R., Royo-Esnal, A., & Westerman, P. R. (2011a). Assessing yield losses caused by the harvester ant *Messor barbarus* (L.) in winter cereals. *Crop Protection*, *30*(9), 1144-1148.

Beattie, A.J. (1989). The effect of ants on grasslands, In Huenneke, L.F., Mooney, H. (Eds.), *Grassland Structure and Function*(pp.105-116): Dordrecht, Netherlands, California Annual Grassland, Kluwer Academic Publishers.

Blatrix, R., Lebas, C., Galkowski, C., Wegnez, P., Pimenta, R.& Morichon, D.(2016). Vegetation cover and elevation drive diversity and composition of ant communities (Hymenoptera: Formicidae) in a Mediterranean ecosystem. *Myrmecological News*, *22*, 119-127.

Bolton, B.(2019). An online catalogue of the ants of the world. Retrieved from https://www.antcat.org.

Brown, J.H., Davidson, D.W.& Reichman, O.J.(1979). An experimental study of competition between seed-eating desert rodents and ants. *American Zoologist*, *19(4)*, 1129-1143.

Cerda, X.& Retana, J.(1994). Food exploitation patterns of two sympatric seed-harvesting ants *Messor bouvieri* (Bond.) and *Messor capitatus* (Latr.) (Hym. Formicidae) from Spain. *Journal of Applied Entomology*, *117*, 268-277.

Cerdan, P.(1989).Etude de la Biologie, de l'écologie et du comportement des fourmis moissonneuses du genre *Messor* (Hymenoptera, Formicidae) en Crau. Thèse, Université de Provence Aix-Marseille, I. 257 pp.

Cissokho, P.S., Cueye, T.M., Sow, E.& Diarra, K.(2015). Substances inertes et plantes à effet insecticide utilisées dans la lutte contre les insectes ravageurs des céréales et légumineuses au Sénégal et en Afrique de l'Ouest. *International Journal of Biological and Chemical Sciences,9(3),* 1644-1653.https://www.ajol.info/index.php/ijbcs/article/view/121826

Collingwood, C.A.(1985). Hymenoptera, Fam. Formicidae of Saudi Arabia. *Fauna of Saudi Arabia, 7,* 230-302.

Detrain, C., & Tasse, O. (2000). Seed drops and caches by the harvester ant *Messor barbarus*: do they contribute to seed dispersal in Mediterranean grasslands? *Naturwissenschaften, 87(8),* 373-376.

FAOSTAT.(2021).*Food and Agriculture Organization of the United Nations*.Retrieved from www.fao.org/faostat/fr/

Gillon, D., Adam, F.& Hubert, B.(1984). Production et consommation de graines en milieu sahélo-soudanien au Sénégal les fourmis, *Messor galla. Ins Soc, 31*, 51–73.

Inouye, R.S., Byers, G.S.& Brown, J.H.(1980). Effect of predation and competition on survivorship, fecundity and community structure of desert annuals. *Ecology, 61*, 1344-1351.

Jolivet, P.(1986).*Les fourmis et les plantes, un exemple de coévolution*. Paris, Éd: Boubee, 254p.

Ladoui, K., Mefti, M.& Benkherbache, N.(2020). Sélection de génotypes d'orge (*Hordeum vulgare* L.) tolérants au stress hydrique par les indices de tolérance a la sécheresse. *Revue Agrobiologia*, *10(1),* 1805-1812.

Lebas, C.(2021). Influence des activités humaines sur la répartition des fourmis du genre *Messor* dans les Pyrénées-Orientales (Hymenoptera: Formicidae: Myrmicinae). *OSMIA*, *9,* 65-76.

Lopez, F., Acosta, F.J.& Serrano, M.(1993). Responses of the trunk routes of a harvester ant to plant density. *Oecologia, 93,*109-113.

Ludwig, J.A.& Whitford, W.G.(1981). Short-term water and energy flow in arid ecosystems, Cambridge University Press, 271–299.

MADR.(2021). Ministère de l'Agriculture et du Développement Rural Direction des Système d'Information, des Statistiques et de la Prospective.

Merienne H, Latil G, Moretto P, Fourcassié V. (2021). Dynamics of locomotion in the seed harvesting ant *Messor barbarus:* effect of individual body mass and transported load mass. PeerJ 9:e10664.

Patil, I. (2021). Visualizations with statistical details: The 'ggstatsplot' approach. *Journal of Open-Source Software,6(61),* 3167.

Plowes, N.J., Johnson, R.A.& Hoelldobler, B.(2013). Foraging behavior in the ant genus *Messor* (Hymenoptera: Formicidae: Myrmicinae). *Myrmecological News, 18,* 33-49.

Richi, K., Richi, F.A., Boungab, K.& Mokabli, A.(2019).Étude de l'infestation des céréales par les nématodes à kyste « Heterodera spp. » et distribution des espèces en cause dans l'Ouest de l'Algérie. *Cahiers Agricultures*, *28 (17)*, 10.

Scherrer, B.(1984). *Biostatistique*. (Gaëten Morin, ed.). Montréal, Paris, Casablanca. p 850.

Torra, J., Atanackovic, V., Blanco-Moreno, J. M., Royo-Esnal, A., & Westerman, P. R. (2016). Effect of patch size on seed removal by harvester ants. *Weed Research*, *56(1)*, 14-21.

Wagner, F.H.& Graetz, R.D.(1981). Animal-animal interactions. In: Goodall,& Perry. (ed.), *Arid Land Ecosystems*, 2, 51-83.

Westerman, P. R., Atanackovic, V., Royo-Esnal, A., & Torra, J. (2012). Differential weed seed removal in dryland cereals. *Arthropod-Plant Interactions*, *6*, 591-599.