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Development of *Sitophilus granarius* (L.), *S. oryzae* (L.) and *S. zeamais* Mots. on kernels of *Triticum monococcum*, *T. dicoccum* and *T. spelta*

Abstract - The aim of the present study meant to examine the development of *Sitophilus granarius, S. oryzae* and *S. zeamais* on *Triticum spelta, T. dicoccum* and *T. monococcum* spikelets and kernels. Absence or poor number of individuals (0-8) on *T. spelta* and *T. dicoccum* is observed for all the species. In the case of *T. monococcum* spikelets the mean number of emerged adults, even if inferior than that one observed on *T. dicoccum* kernels, ranges from 52 for *S. oryzae* and *S. zeamais* to 157 for *S. granarius.* In fact the kernel is not completely isolated from the outside, as glumes and inner glumes are not contiguos to the kernels. A greater number of emerged adults is observed on *T. spelta* kernels, except *S. oryzae*, where the highest number of individuals occurs on *T. dicoccum* spikelets. The mean number of individuals emerged from *T. monococcum* kernels is inferior than *T. spelta* and *T. dicoccum* kernels. *T. monococcum* kernels is in fact smaller, about 2/3, than *T. spelta* and *T. dicoccum.*
In laboratory at 25°C and 70 ± 5% R. H. the beginning of emergence for *S. granarius* started 33-38 days after egg laying while *S. oryzae* and *S. zeamais* started respectively 29-40 and 33-40 after the ovideposition. Also for these species the mean of the development period seems to be significantly shorter for *T. dicoccum* kernels while the longest period is observed on *T. monococcum* spikelets.

Riassunto - *Sviluppo di* Sitophilus granarius *(L.),* S. oryzae *(L.) e* S. zeamais *Mots. su* Triticum monococcum, T. dicoccum *e* T. spelta.

Sitophilus granarius, S. oryzae e *S. zeamais* sono stati allevati su spighette e cariossidi di *Triticum spelta, T. dicoccum* and *T. monococcum.* Per tutte le specie si sono osservati sfarfallare da 0 a 8 individui, sulle cariossidi protette da spighetta di *T. spelta e T. dicoccum.* Nel caso invece di *T. monococcum* il numero medio di adulti, anche se inferiore a quello osservato sulle cariossidi non protette da spighette, varia da 52 per *S. oryzae* e *S. zeamais* a 157 per *S. granarius.* La cariosside di *T. monococcum* infatti non è completamente isolata dall'esterno, in quanto glume e glumelle non sono perfettamente aderenti. Si osserva un maggior numero di individui sfarfallati da cariossidi di *T. spelta,* ad eccezione di *S. oryzae,* in cui il numero più elevato di individui si verifica su spighette di *T. dicoccum.*

D.P. Locatelli planned and directly followed the test. Data were collected by L. Guarino. Results were discussed and processed by D.P Locatelli and L. Süss.

Nel caso invece di cariossidi non protette, il numero medio di individui in *T. monococcum* è inferiore rispetto a quello verificato per *T. spelta* e *T. dicoccum.* La cariosside di *T. monococcum* è infatti più piccola, circa due terzi rispetto a quella di *T. spelta* e *T. dicoccum*..
L'inizio degli sfarfallamenti degli adulti a 25°C e 70±5% U.R. si verifica per *S. granarius* dopo 33-38 giorni mentre nel caso di *S. oryzae e S. zeamais* rispettivamente dopo 29-40 e 33-40. Per tutte le specie il numero medio di giorni necessario per lo sfarfallamento degli adulti è significatamente più breve su *T. dicoccum,* più lungo nel caso delle spighette di *T. monococcum* .

Key words: *Sitophilus granarius, S. oryzae, S. zeamais*, development, *Triticum monococcum, T. dicoccum, T. spelta.*

INTRODUCTION

Hulled wheat species Einkorn (*Triticum monococcum*), Emmer (*Triticum dicoccum*), Spelt (*Triticum spelta*) are among the most ancient cereal crops of the Mediterranean region. In Europe, particularly in Germany, Belgium and Switzerland, spelt flour is largely used in bread-making and other bakery products. In Italy these cereals are still being used in rural areas to prepare traditional dishes.

The cereals show different susceptibility to attacks by insects; the susceptibility depends on the physical and nutritional features of the seeds, on the dimension of the kernels, on the texture of the seed-coat glume and the inner glume and on the strength of the pericarp (Russell,1962; Teotia & Singh, 1968; Sharifi, 1972; Singh *et al.*, 1974; Tipping *et al.*, 1986; Kossou *et al.,* 1995; Vowotork,1995).

Urrello and Wright (1989) showed for *Sitophilus zeamais* Mots. bred on different varieties of maize, that the insect chooses preferential points for eggs laying and emergence of adults according to the hardness of the kernel endosperm. It has been observed for *S. zeamais* reared on rice at different stages of the milling process that the aleurone layer and the embryo, which are enclosed in the pericarp, contain oviposition stimulant (Arakaki & Takahashi, 1982).

There are very few references to the development of the species of genus *Sitophilus* on spelt (Sinha, 1969; 1971; Trematerra *et al.,* 1996).

The aim of the present study was to examine the development of *Sitophilus granarius* (L.), *S. oryzae* (L.) and *S. zeamais* Mots. on *Triticum spelta, T. dicoccum* and *T. monococcum* spikelets and kernels.

MATERIALS AND METHODS

The cereals used in the experiments were *T. spelta, T. dicoccum* and *T. monococcum* spikelets and kernels, all obtained from Istituto Sperimentale per la Cerealicoltura, Ministero per le Politiche agricole - Section of S. Angelo Lodigiano (Lodi) - Italy.

T. spelta and *T. dicoccum* show spikelets with glumes, lemma and palea very contiguous to the two kernels. In *Triticum monococcum* there is only one kernel; glumes, lemma and palea are more distant from kernel at apex.

Before starting the tests all the substrata were placed in a freezer at a temperature of -20°C for 45 days in order to eliminate the possible presence of Arthropods.

The stock cultures of *S. granarius, S. oryzae* and *S. zeamais* were obtained from the Istituto di Entomologia agraria of Milan, where they had been maintained for several years free of any chemical treatment. These insects are reared on wheat in the laboratory at 25°C and 70±5% R.H., and with 12 hours of light alternating with 12 hours of darkness. The experiment was carried out under the same conditions.

Adults of these species, 100 individuals of mixed sex and 5-15 days age, were released into a 200ml polystyrene container (diameter 120 mm, height 65 mm) containing 30 g of spikelets or kernels[(1)]. Such containers, closed with gauze (120 mesh) to allow for adequate air circulation, were placed in a thermostatic cell. The adults were removed after 5 days. The days were then counted until the adults of the new generation began to emerge. The number of adults obtained from the cereals was checked every day; the adults were counted and removed on a daily basis.

4 replications were carried out for every tested substrate with each species. The developmental period was reckoned from eggs laying to the time when 50% of the total adults emerged. Means of the emerged adults and of the development periods were compared using Duncan's multiple range test ($P<0.05$) procedure. The tests were performed using the SPSS for Windows version 5.01. The statistical evaluation did not show significant differences among means on original and angular transformed data.

In order to evaluate possible interspecific differences among he t hree species considered on the hulled wheat, a multifactorial analysis of correspondence has been performed using CANOCO release 3.12 (Cornell ecology program DECORAMA).

RESULTS

In tables 1-3 the means of the emerged adults and the means of development periods together with their relative standard deviations are listed. In the same tables the maximum and minimum number of emerged adults are shown. For all the species very few or no individuals were observed on *T. spelta* and *T. dicoccum* spikelets.

A greater number of adults emerged on *T. spelta* kernels was recorded with the

(1) *Triticum*	spikelets	kernels
spelta	362±10	741±9
dicoccum	567±8	759±9
monococcum	1098±14	1586±27

Mean number of kernels of *Triticum spelta*, *T dicoccum* and *T. monococcum* in 30g of cereal as spikelets and as kernels.

Table 1 - Mean of emerged adults, mean of development period (time requested to obtain 50% of adult emerged) and minimum and maximum of adults emerged on four replicates for S. granarius *on* Triticum spelta, T. dicoccum *and* T. monococcum *spikelets and kernels.*

TRITICUM	EMERGED ADULTS* (±S.D.)	DEVELOPMENT PERIOD	MIN. AND MAX. EMERGED ADULTS
spelta spikelets	2 (±1) a	0 a	1 – 4
spelta kernels	320 (±42) d	45 (±0.6) d	279 – 357
dicoccum spikelets	8 (±4) a	0 a	4 – 11
dicoccum kernels	302 (±13) d	39 (±1) b	286 – 315
monococcum spikelets	157 (±10) b	47 (±0.5) e	144 – 166
monococcum kernels	267 (±18) c	43 (±0.5) c	249 – 284

* Means followed by the same letter are not significanlty different (P <0.05, ANOVA, Duncan's test).

Table 2 - Mean of emerged adults, mean of development period (time requested to obtain 50% of adult emerged) and minimum and maximum of adults emerged on four repliclates for S. oryzae *on* Triticum spelta, T. dicoccum *and* T. monococcum *spikelets and kernels.*

TRITICUM	EMERGED ADULTS* (±S.D.)	DEVELOPMENT PERIOD	MIN. AND MAX. EMERGED ADULTS
spelta spikelets	0 a	0 a	0
spelta kernels	239 (±19) c	44 (±1) c	215 – 260
dicoccum spikelets	1 (±1) a	0 a	0 – 2
dicoccum kernels	296 (±37) d	38 (±1.5) b	258 – 334
monococcum spikelets	52 (±12) b	49 (±3) e	37 – 67
monococcum kernels	218 (±22) c	46 (±0.5) d	198 – 240

* Means followed by the same letter are not significanlty different (P <0.05, ANOVA, Duncan's test).

Table 3 - Mean of emerged adults, mean of development period (time requested to obtain 50% of adult emerged) and minimum and maximum of adults emerged on four repliclates for S. zeamais *on* Triticum spelta, T. dicoccum *and* T. monococcum *spikelets and kernels.*

TRITICUM	EMERGED ADULTS* (±S.D.)	DEVELOPMENT PERIOD	MIN. AND MAX. EMERGED ADULTS
spelta spikelets	4(±3) a	0 a	1 - 8
spelta kernels	354 (±20) e	42 (±2) c	327 - 376
dicoccum spikelets	1 (±1) a	0 a	0 - 3
dicoccum kernels	258 (±22) d	39 (±0) b	238 - 285
monococcum spikelets	57 (±18) b	53 (±3) e	31 - 69
monococcum kernels	165 (±18) c	46 (±0) d	150 - 191

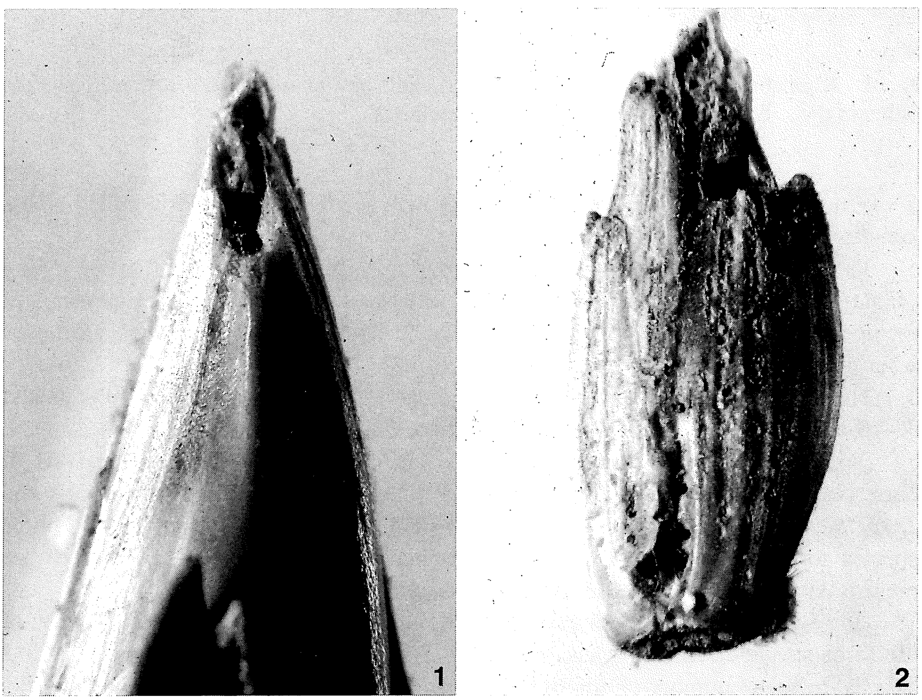
* Means followed by the same letter are not significanlty different (P <0.05, ANOVA, Duncan's test).

exception of *S. oryzae* where the highest number of individuals occurred on *T. dicoccum* kernels.

The Duncan's test, performed on the mean of emerged adults, indicated in *S. zeamais* differences among all species of *Triticum*, whereas in *S. oryzae* the test showed no significant differences between *Triticum spelta* and *T. dicoccum* kernels. Several attempts of attack by these insects can be observed by a stetoscope microscope, especially in the apical area of spikelets of *T. spelta*, *T. dicoccum*, characterized by less resistant palea and lemma, sometimes less contiguos to kernel (Figs. 1-2). In some cases insects can pierce glumes but not palea and lemma. When there are spikelets with glumes not very contiguos to kernel, insects can pierce directly glumes. Spikelets of *T. monococcum* are easily pierced as glume, lemma and palea are more distant from the kernel near the apex.

For these species the mean of the development period seems to be significantly shorter when *T. dicoccum* kernels is considered while the longest period of development was observed on *T. monococcum* spikelets.

Figures 3-5 show the normalized cumulative emergence curves of *S. granarius,*



Figs. 1-2 - Attempts of attack carried out on *Triticum dicoccum* by a female of *Sitophilus oryzae* (fig. 1); on *Triticum spelta* carried out by *Sitophilus zeamais* (fig. 2).

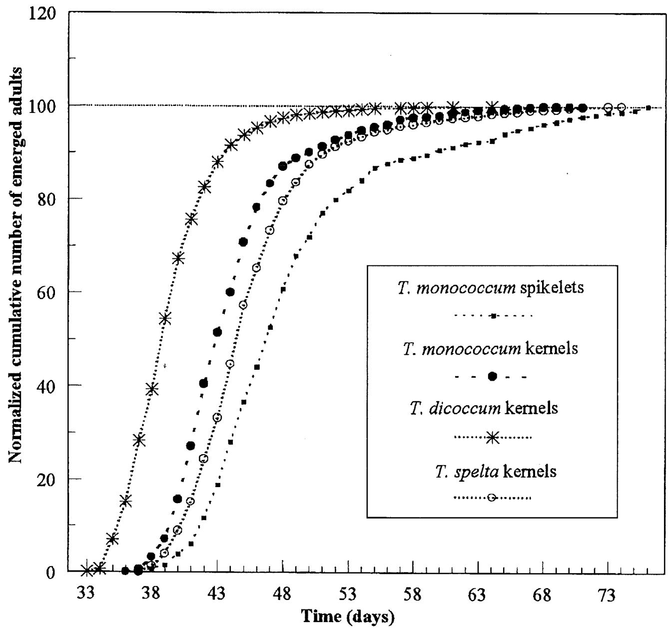


Fig. 3 - Normalized cumulative mean number of adults of *Sitophilus granarius* emerged from different diets. Each point is the mean of four replicates.

S. oryzae and *S. zeamais*. In general insect growth seems to be easier on hulled-wheat kernels.

The beginning of emergence for *S. granarius* started 33-38 days after egg laying (Table 1). In the case of *T. spelta* and *T. dicoccum* spikelets no development was recorded. No significant differences were found for emerged adults of *S. granarius* when fed on *T. spelta* or *T. dicoccum* kernels .

The beginning of emergence of *S. oryzae* and *S. zeamais* started 29-40 days and 33-40 days respectively after the ovideposition (Tables 2-3).

Figure 6 show the results obtained by performing a multifactorial analysis of correspondence considering at the same time *S. granarius, S. oryzae, S. zeamais* and *T. spelta*, *T. dicoccum*, *T. dicoccum* spikelets and kernels. The proximity of the three species to the axis origin indicates that basically no interspecific differences are present among the species of *Sitophilus* considered.

However some observations can be made by looking at the spatial distribution of the three species. *Triticum spelta* and *T. dicoccum* spikelets are placed far from the axis as the mean number of emerged adults is absent or low. *T. monococcum* spikelet is placed far from the axis as a lesser number of individuals emerged from this substrate. *S. granarius*, *S. oryzae* and *S. zeamais* are placed in 3 different areas of the

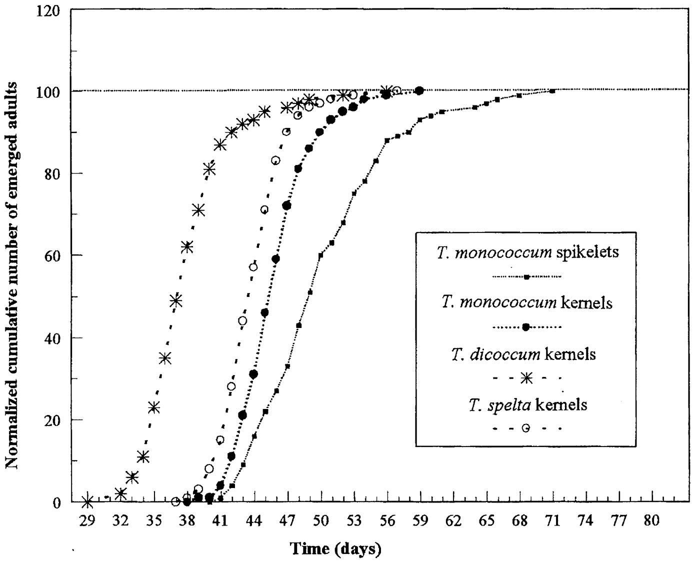


Fig. 4 -. Normalized cumulative mean number of adults of *Sitophilus oryzae* emerged from different diets. Each point is the mean of four replicates.

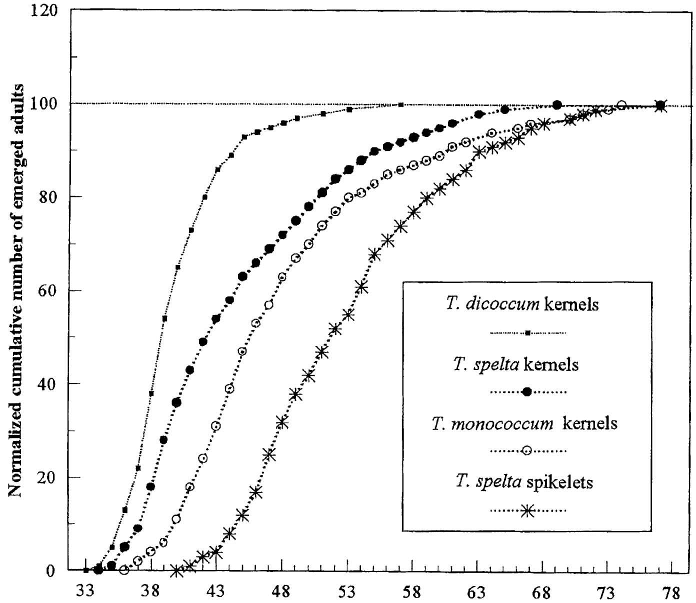


Fig. 5 - Normalized cumulative mean number of adults of *Sitophilus zeamais* emerged from different diets. Each point is the mean of four replicates.

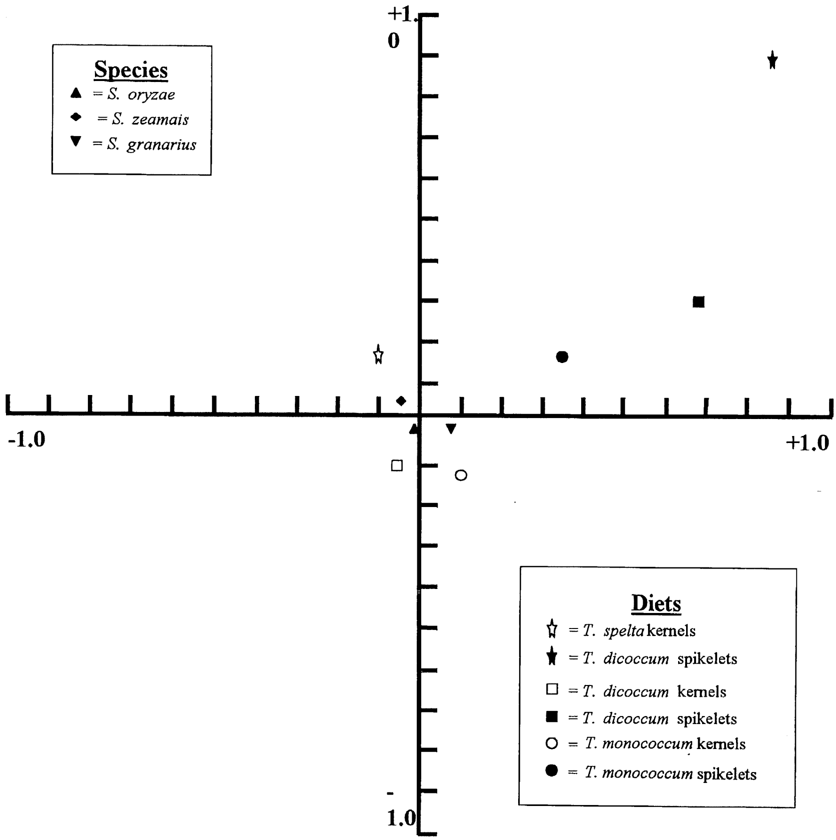


Fig. 6 - Multifactorial analysis of correspondence. All the species and diets are considered simultaneously.

two axis. *S. granarius* especially shows a greater number of emerged adults on *T. spelta* and *T. dicoccum* kernels, while *S. zeamais* on *T. spelta* kernels and *S. oryzae* on *T. dicoccum* kernels.

CONCLUSIONS

Absence or low number of emerged adults of *S. granarius*, *S. oryzae* and *S. zeamais* on *T. spelta* and *T. dicoccum* spikelets is observed. These cereals are both characterized by glumes and inner glumes which completely cover their kernels. In fact the presence of glumes and inner glumes considerably hinders the establishment of cells for ovideposition and adult feeding. Bagheri-Zenouz (1984) observed that the main factors influencing fecundity of *Sitophilus granarius* were relative humidity, grain moisture content and grain hardness. In the case of *Sitophilus oryzae* the rates of oviposition and development are affected by the physical nature of the kernels, bran and endosperm (Singh *et al.*, 1974). It was observed that the oviposition response of *Sitophilus oryzae* in different maize hybrids of about the same size and flint nature, may have been related to the chemical nature of the grain and its coat (Singh *et al.*, 1973). Also Sinha (1971) observed that hulled emmer wheat was highly resistant to *Sitophilus oryzae* and to *S. zeamais*. The few individuals which emerged from *T. spelta* e *T. dicoccum* spikelets were laid on kernels which were mechanically damaged. Sauphanor (1988) confirmed the importance of the hermetic seal of the husk in providing resistance to *S. oryzae*, *S. zeamais*, *Rhyzopertha dominica* and *Sitotroga cerealella* and he showed that mechanical damage is more serious as a point of entry than lack of a close join between lemma and palea.

In the case of *T. monococcum* spikelets the mean number of emerged adults varies from 52 for *S. oryzae* and *S. zeamais* to 157 for *S. granarius*. In fact the kernel is not completely protected from the outside, as the glumes and inner glumes are not closed: as a consequence the female is easily able to locate the area where the kernel is unprotected from the outside.

The mean number of adults emerged from *T. monococcum* kernels is lower than that for *T. spelta* and *T. dicoccum* kernels. *T. monococcum* kernel is in fact about two thirds smaller than *T. spelta* and *T. dicoccum.* As other Authors observed, the dimension of the kernel and consequently the quantity of nutritional elements available affects the development of the larvae. Teotia and Singh (1968) observed on different cereals that larvae of *S. oryzae* developed better and bigger adults emerged from the largest seeds. Also Shazali (1986) observed that adults of *S. oryzae* are more prolific on the large grains of sorghum than on the small ones: the number of eggs laid, the number of eggs per grain and the amount of grain eaten was highest in large kernels.

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