

Pear Ester Based Lures for the Codling Moth *Cydia pomonella* L. – A Summary of Research Efforts in Hungary

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For acceptable capture efficiency it was necessary to add acetic acid to pear ester for successful trapping of codling moth populations in Hungary. The activity of pear ester on its own was very weak and unsatisfactory. Pear ester+acetic acid baited traps caught on an average 25% (mean of 6 tests) of the catch in pheromone traps. Traps with pear ester+acetic acid were clearly advantageous as compared to pheromone traps in that they caught not only males but also females (both virgins and mated) in a high percentage. Traps baited with pear ester+acetic acid clearly outperformed high-load pheromone lures in orchards with mating disruption and should be the right choice for the grower for sampling populations of codling moth in a mating disruption situation. In orchards with no mating disruption the relative inefficiency of pear ester+acetic acid baited traps as compared to pheromone traps can easily be overcome by applying more traps than usual. Thus the overall codling moth numbers caught will become higher and would make any conclusions drawn more reliable. Traps baited with pear ester+acetic acid always caught more when set at the highest branches (3.0–3.5 m) than when set lower (1.5–1.8 m) on trees.

Keywords: *Cydia pomonella*, female-targeted lure, pear ester, acetic acid, high-load pheromone, trapping.

The codling moth (*Cydia pomonella* L.) (Lepidoptera, Tortricidae) counts among the most important insect pests of apple production worldwide. Sex pheromone-baited traps play an important role in codling moth detection, monitoring and forecast. Synthetic pheromone-baited traps attract only male moths. This has the major disadvantage that “the trap catches of males must usually be interpreted in terms of the behaviour of the females, thus adding to the complexity of that interpretation” (Wall, 1985). Capture of female insects beside males, on the other hand, would provide a better opportunity for: 1) more precise monitoring, leading to more accurate decision-making on timing of control strategies against a given pest species (Wall, 1985); 2) more efficient mass trap-

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ping by direct population reduction catching gravid females (Bakke and Lie, 1985), as reported, among others, for *Ceratitis capitata* Wied. (Diptera: Tephritidae) (Katsoyannos et al., 1999); 3) the application of the lure-and-kill method, as reported for example in *Anastrepha suspensa* Loew (Diptera: Tephritidae) (Heath et al., 2009); 4) efficacy assessment of the sterile male technique by determining egg sterility of captured females (e.g. in *C. capitata*, Miranda et al., 2001).

Research efforts to develop a female-targeted lure for the codling moth became more intensive also with the advent of mating disruption against *C. pomonella* (Cardé and Minks, 1995; Witzgall et al., 2008), as in an orchard with successful mating disruption traps baited with synthetic sex pheromone will not work (since mating disruption disturbs the orientation of male moths to monitoring traps as well). It is often recommended in orchards under mating disruption to place pheromone traps high in the canopy and on the borders of orchards, or to increase the lure loading (Gut and Brunner, 1996), however, these methods in many cases do not give satisfactory results (Il'ichev, 2004).

Ethyl-(*E,Z*)-2,4-decadienone (pear ester), a compound isolated from ripe pears has been reported to be a potent attractant for both male and female codling moths (Light et al., 2001; Light and Knight, 2005). Later, Landolt et al. (2007) reported that catches of both female and male codling moths were significantly increased by the addition of acetic acid to synthetic pear ester. Recently this combination has been confirmed to be effective also in European populations of codling moth (Hári et al., 2011).

The objective of the present study was to summarize research results obtained in recent years in Hungary testing pear ester-based lures. These research efforts were focused on:

- 1) confirming whether the presence of both pear ester and acetic acid is necessary for best attraction in Hungary,
- 2) comparing activity of the best pear ester-based female targeted lure with that of the synthetic sex pheromone-baited traps,
- 3) comparing activity of the best female-targeted lure with that of high-load pheromone lures in orchards with mating disruption against codling moth and
- 4) investigating whether traps with female-targeted lures set out high in the canopy or at lower levels work better.

Materials and Methods

Field tests

Tests were run in apple orchards in Hungary (Table 1). Unless otherwise stated traps were set up in the canopy of trees at ca 1.5–1.8 m high, attached to branches. Traps were arranged as blocks so that each block contained one trap of each treatment. Traps within blocks were separated by 8–10 m, and blocks were sited at least 30 m apart. Traps were inspected at some days' intervals (preferably twice weekly), when captured insects were recorded, sexed and removed.

Traps

In the tests, sticky delta traps CSALOMON® RAG (produced by Plant Prot. Inst., CAR HAS, Budapest, Hungary) were used. These have routinely been used for the trapping of many moths (Szócs, 1993; Tóth and Szócs, 1993); photos of the trap can be viewed at www.csalomontraps.com. Sticky inserts of traps were replaced regularly to prevent the surface to become fully covered by insects.

Table 1

Sites and periods of field tests and number of traps for monitoring codling moth

Experiment No.	Location	Description of orchards	Period	Number of blocks
Exp. 1A	Halásztelek, Pest county	abandoned apple orchard	9 July–17 August, 2007	10
Exp. 1B	Halásztelek, Pest county	abandoned apple orchard	17 July–24 August, 2007	5
Exp. 1C	Zalasárszeg, Zala county	commercial pear orchard	16 June–4 August, 2008	4
Exp. 2A	Halásztelek, Pest county	abandoned apple orchard	9 July–17 August, 2007	10
Exp. 2B	Eperjeske, Borsod-Abaúj-Zemplén county	organic apple orchard	5 May–1 September, 2011	4
Exp. 2C	Soroksár, Budapest	commercial apple orchard	3 May–28 August, 2012	4
Exp. 2D	Debrecen Pallag, Hajdú-Bihar county	backyard gardens	2 May–28 August, 2012	4
Exp. 2E	Eperjeske, Borsod-Abaúj-Zemplén county	organic apple orchard	16 May–29 August, 2013	6
Exp. 2F	Soltvadkert, Bács-Kiskun county	commercial orchard	14 May–13 September, 2013	8
Exp. 3A	Tordas, Fejér county	apple orchard with mating disruption against codling moth	6 May–30 August, 2011	4
Exp. 3B	Soroksár, Budapest	apple orchard with mating disruption against codling moth	3 May–28 August, 2012	4
Exp. 4A	Érd-Elviramajor, Fejér county	commercial apple orchard	1–28 August, 2012	5
Exp. 4B	Tordas, Fejér county	apple orchard with mating disruption against codling moth	14 June–3 September, 2013	5
Exp. 4C	Csorvás, Békés county	commercial apple orchard	6 May–30 August, 2013	4
Exp. 4D	Felsőzsolca, Borsod-Abaúj-Zemplén county	commercial apple orchard	6 May–30 August, 2013	6
Exp. 4E	Eperjeske, Borsod-Abaúj-Zemplén county	organic apple orchard	16 May–29 August, 2013	6

Baits

Codling moth pheromone lures

Codling moth pheromone lures (commercially available, produced by Plant Prot. Inst., CAR HAS, Budapest, Hungary) were formulated on red rubber septa. Pheromone lures were replaced with new ones after 4 weeks of field exposure.

High-load pheromone lures (Deltastop) were obtained from Biocont Magyarország Kft. (produced by PROPHER s.r.o., Czech Republic). Pheromone lures were replaced with new ones after 5 weeks of field exposure.

Polyethylene bag (PE bag) dispensers (for acetic acid and acetic acid with pear ester)

A 1-cm piece of dental roll (Celluron[®]; Paul Hartmann, Heidenheim, Germany) was placed into a tight polyethylene sachet (ca 1.5 × 1.5 cm) made of 0.02-mm linear polyethylene foil. The dispenser was attached to a plastic strip (8 × 1 cm) for easy handling when assembling the traps. For making up the baits, compounds were administered onto the dental roll and the opening of the polyethylene bag was heat-sealed. Previous results with acetic acid tested against other pests showed that this type of dispenser was active for several weeks of field exposure (i.e. Tóth et al., 2002); hence, we decided to renew the lures at 2- to 3-week intervals.

Rubber dispensers (for pear ester)

Lures for the tests were prepared by using pieces of rubber tubing (no. MSZ 9691/6; Taurus, Budapest, Hungary; extracted 3 × in boiling ethanol for 10 min, then 3 × in methylene chloride overnight).

All types of dispensers were wrapped in aluminum foil and stored at –30 °C until use. When making the pear ester or acetic acid lures, the required amounts of compounds were administered to the surface (rubber) or into the PE bag dispensers in hexane solutions. After allowing the solvent to evaporate for 15 min, the PE bag dispensers were heat sealed.

Experimental details

Experiment 1. This test was aimed at studying the effect of the addition of acetic acid to pear ester. Treatments included pear ester (6 mg on rubber dispenser), acetic acid (400 mg in PE bag dispenser), traps with both baits of pear ester and acetic acid and unbaited controls. The test was conducted at Halásztelek (Exp. 1A and 1B), and Zalasárszeg (Exp. 1C) (Table 1). Lures used in Exp. 1A (pear ester and acetic acid) originated from Peter Landolt (USA). For description of these lures please refer to Landolt et al. (2007).

Experiment 2. In this test we compared the performance of traps baited with pear ester (6 mg) plus acetic acid (400 mg) formulated into one PE bag dispenser vs. commercial codling moth pheromone lures. The test was conducted at Halásztelek (Exp. 2A), Eperjeske (Exp. 2B, 2E), Soroksár (Exp. 2C), Debrecen (Exp. 2D) and Soltvadkert (Exp. 2F) (Table 1).

Experiment 3. The objective was to compare the performance of traps baited with pear ester (6 mg) plus acetic acid (400 mg) formulated into one PE bag dispenser vs. high-load codling moth pheromone lures in orchards treated with mating disruption against the codling moth. The test was conducted at Tordas (Exp. 3A) and Soroksár (Exp. 3B) (Table 1).

Experiment 4. The objective of this test was to compare catches of traps baited with the combination of pear ester plus acetic acid (6 mg and 400 mg, resp., formulated into one PE bag dispenser) set out at the height of 1.5–1.8 m vs. traps set out at the highest branches of the crown of the tree at 3.0–3.5 m. The test was conducted at Érd-Elviramajor (Exp. 4A), Tordas (Exp. 4B), Soroksár (Exp. 2C), Csorvás (Exp. 4C), Felsőzsolca (Exp. 4D) and Eperjeske (Exp. 4E) (Table 1).

Statistical analysis

The catches from field trapping tests were transformed using $(x+0.5)^{1/2}$ (Roelofs and Cardé, 1977) and analysed by Student *t*-test or ANOVA as appropriate. If the ANOVA yielded significance, then treatment means were separated by Games–Howell test (Games and Howell, 1976; Jaccard et al., 1984). Where one of the treatments caught no insects the Bonferroni–Dunn test (Dunn, 1961) was used to check whether mean catches in other treatments were significantly different from zero catch (see also Figure legends).

All statistical procedures were conducted using the software packages StatView® v4.01 and SuperANOVA® v1.11 (Abacus Concepts, Inc., Berkeley, CA, USA).

Results

Effect of the addition of acetic acid to pear ester

Pear ester baited traps caught significantly more than unbaited controls in one (Fig. 1, Exp 1A) out of 3 tests. This was also true for traps with acetic acid only (Fig. 1). The only treatment which caught more than unbaited control in all 3 tests was the combination of pear ester plus acetic acid (Fig. 1). This combination caught numerically the greatest numbers in all 3 tests, however, the difference from traps with pear ester or acetic acid only was significant in only one of the 3 experiments.

Comparing pear ester+acetic acid lure with pheromone lure

In all experiments aimed at comparing the pear ester + acetic acid lure with the pheromone lure, traps with pear ester + acetic acid caught significantly less in all 6 tests (Fig. 2). Numbers captured in pear ester + acetic acid baited traps ranged from 6% to 56% of numbers in pheromone traps in the same experiment. Females were caught only in pear ester + acetic acid baited traps. Female percentages in the catch ranged from 44% to 76% (Fig. 2, Exp 2A and Exp 2F, resp.).

Comparing pear ester+acetic acid lure with high-load pheromone lure in orchards with mating disruption

In the orchards with mating disruption control of the codling moth, the pear ester+acetic acid combination caught more than the high-load pheromone in both cases (Fig. 3). The catch of the high-load pheromone was not significantly higher than that of unbaited controls. When the seasonal distribution of catches was compared in traps with pear ester+acetic acid or the high-load pheromone, the traps with the latter caught negligible numbers of codling moth and these catches were not sufficient to follow the flight pattern of the pest (Fig. 4), whereas information on the occurrence and flight of codling moth was obtained with traps baited with pear ester+acetic acid.

Traps with pear ester+acetic acid caught again females in high percentage (Fig. 3). Out of all females caught 67% were mated in Exp 3B.

Comparing traps baited with pear ester + acetic acid set out high or low on trees

Traps with pear ester+acetic acid set high up on the highest branches (3.0–3.5 m) caught invariably more codling moths than traps set out lower in the crown (1.5–1.8 m) in all 5 tests (Fig. 5), and the difference was highly significant. Female ratios in catch were similar no matter whether the traps were set out high or low, the only exception being at Tordas (Fig. 5, Exp. 4B), but in this particular experiment only a total of 5 moths were caught in the traps set out low, so due to this low number the female percentage does not seem to be representative. (In Exp. 4A moths captured were not sexed.)

Discussion

We conclude from results in Exp. 1 (Fig. 1) that for acceptable capture efficiency it is necessary to add acetic acid to pear ester for successful trapping of codling moth populations also in Hungary, confirming the report of Landolt et al. (2007) for codling

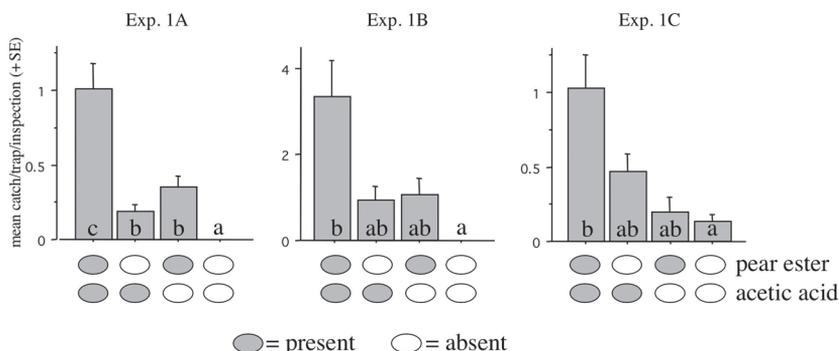


Fig. 1. Mean catches of codling moths in sticky traps baited with pear ester, acetic acid or pear ester+acetic acid and in unbaited traps. Total moth numbers caught in test: 140, 107 and 110 for Exp. 1A, 1B and 1C, resp. Means with same letter within one diagram not significantly different at $P=5\%$ by ANOVA, Games–Howell, Bonferroni–Dunn

moth populations in the USA. In our tests the activity of pear ester on its own was very weak and unsatisfactory. This confirms earlier preliminary results from Hungary (Tóth et al., 2009). In another study conducted in Europe, the same inefficiency of pear ester was reported from Bulgaria also (Kutinkova et al., 2005). In conclusion, in ensuing tests we always used the combination of pear ester + acetic acid for best female-targeted lure.

In comparisons of traps baited with the pheromone or with the pear ester + acetic acid combination in the present study, pheromone traps always outperformed the pear ester + acetic acid lures. In experiments of this study pear ester + acetic acid baited traps caught on an average 25% (mean of 6 tests, Fig. 2) of the catch in the pheromone traps. This corresponds well with results of an earlier study from Hungary, where pear ester containing lures caught an average of 20% (calculated from data of 5 separate experiments) of the moth numbers in pheromone-baited traps (Hári et al., 2011).

Apart from the present study, we know only of the publication of Hári et al. (2011) which compared capture intensity of pear ester + acetic acid baited traps with that of pheromone traps. There are several reports in the literature on comparing the performance of traps baited with pear ester only vs. pheromone traps which yielded variable results (Ioriatti et al., 2003; Il'ichev, 2004; Thwaite et al., 2004; Knight and Light 2004, 2005a, 2005b; Knight et al., 2005; Light and Knight, 2005; Mitchell et al., 2008). Due to the very

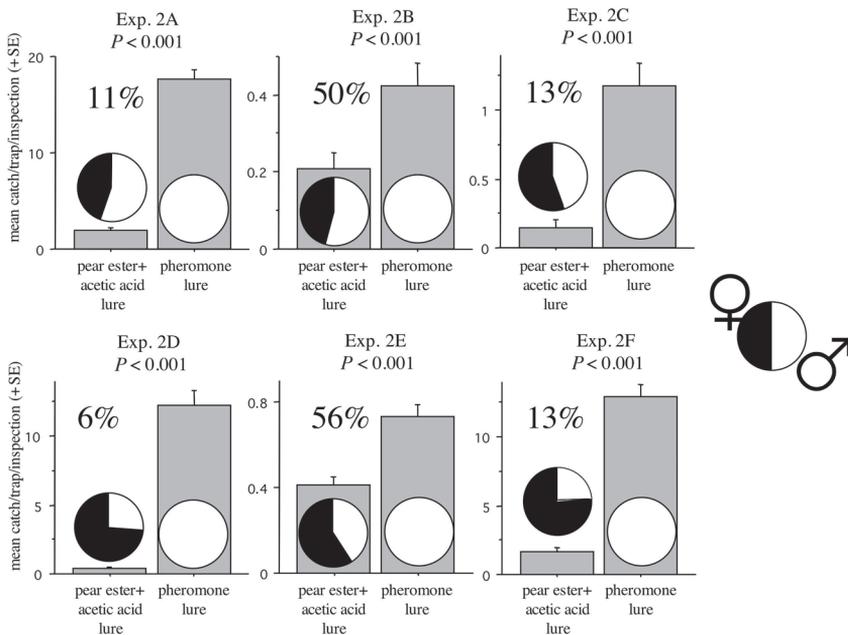


Fig. 2. Mean catches of codling moths in sticky traps baited with pheromone or pear ester + acetic acid. Total moth numbers caught in test: 2145, 73, 159, 780, 219 and 1988 for Exp. 2A, 2B, 2C, 2D, 2E and 2F, resp. Circles in or above a column show sex ratio of moths caught in that particular treatment. Percentages in large font within each diagram show percentage of moths caught by pear ester + acetic acid lure vs. moths caught by pheromone lure in the given experiment.

P values derive from Student *t*-test

low activity of pear ester on its own in Hungary (present study) we believe that probably it is not worthwhile to conduct a comparison between pear ester only vs. the pheromone.

Traps with pear ester + acetic acid were clearly advantageous as compared to pheromone traps in that they caught not only males but also females in a high percentage in the present study. Both virgin and mated females were caught. We suggest that probably female percentages in the catch of pear ester + acetic acid baited traps resemble sex ratio in the local population, although steady experimental proof of this is still missing.

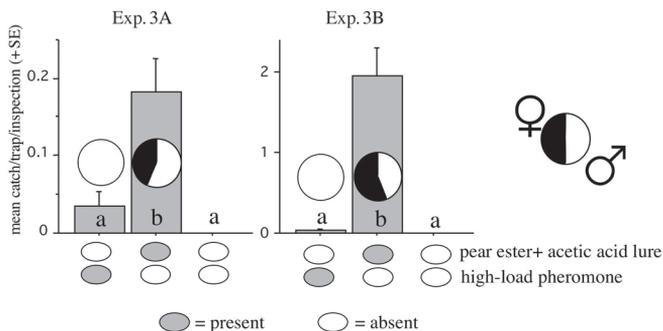


Fig. 3. Mean catches of codling moths in sticky traps baited with high-load pheromone or pear ester + acetic acid in orchards with mating disruption against codling moth. Total moth numbers caught in test: 19 and 135 for Exp. 3A and 3B, resp. Circles in or above a column show sex ratio of moths caught in that particular treatment. Means with same letter within one diagram not significantly different at $P = 5\%$ by ANOVA, Games–Howell, Bonferroni–Dunn

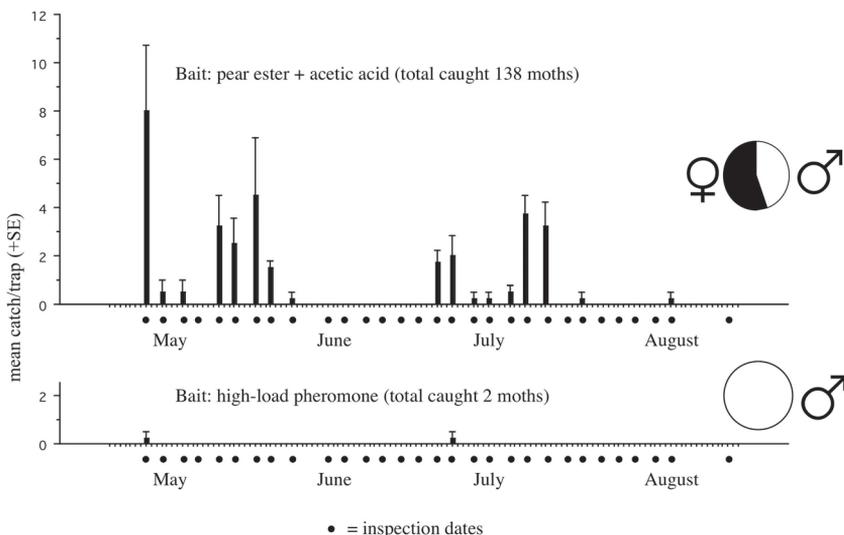


Fig. 4. Seasonal distribution of mean catches of codling moths in sticky traps baited with high-load pheromone or pear ester + acetic acid in and orchard with mating disruption against codling moth (Exp. 3B). Circles in each diagram show sex ratio of moths caught in that particular treatment

Traps baited with pear ester + acetic acid clearly outperformed high-load pheromone lures in orchards with mating disruption and should be the right choice for the grower for sampling populations of codling moth in a mating disruption situation.

In other situations (i.e. in orchards with no mating disruption) the relative inefficiency of pear ester + acetic acid baited traps as compared to pheromone traps can easily be overcome by applying more traps than usual for detection and monitoring (i.e. in a routine monitoring situation instead of the usual 2 pheromone traps per site one should use 4 or 6 traps with pear ester + acetic acid), as already suggested by Hári et al. (2011). Thus the overall codling moth numbers caught will become higher and would make any conclusions drawn more reliable.

Since catch numbers in pear ester + acetic acid baited traps are less robust than in pheromone traps, it is of utmost importance to observe technical optima in applying the traps, i.e. trap height. From results of the present study it is strongly suggested that pear ester + acetic acid baited traps be suspended from the highest branches of the tree even if this makes inspecting the traps more awkward. It has been reported previously also for pheromone traps that they catch more codling moths when set high in the canopy (Riedl et al., 1979).

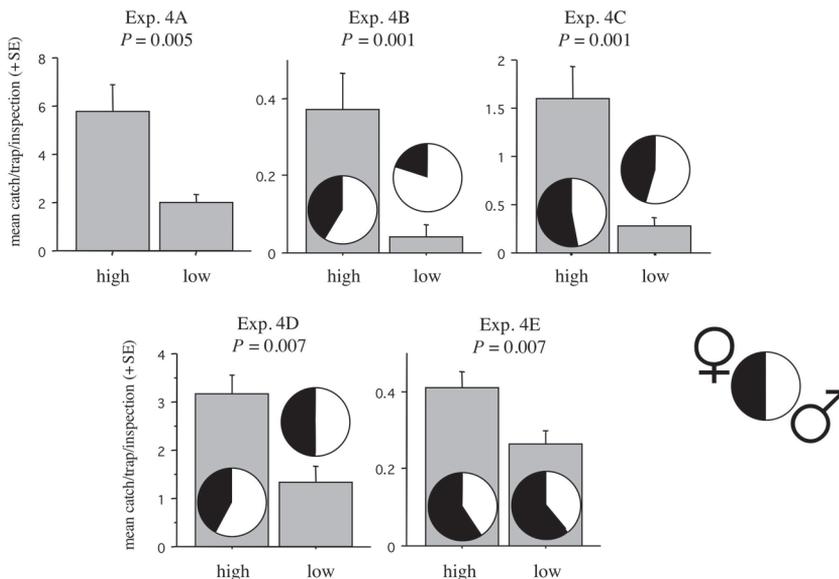


Fig. 5. Mean catches of codling moths in sticky traps baited with pear ester + acetic acid set out high (3.0–3.5 m) or low (1.5–1.8 m) on trees. Total moth numbers caught in test: 39, 29, 75, 27 and 130 for Exp. 4A, 4B, 4C, 4D and 4E, resp. Circles in or above a column show sex ratio of moths caught in that particular treatment (catches in Exp. 4A were not sexed). *P* values derive from Student *t*-test

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