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Trap cropping: An ecological tool for sustainable pest management: A review

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Abstract
Trap cropping is a sustainable and eco-friendly cultural strategy within Integrated Pest Management (IPM) that reduces insect pest pressure by diverting pests from the main crop to more attractive host plants. Its success relies on insect host-selection behavior, crop diversity, spatial arrangement, and ecological interactions within agro-ecosystems. Trap crops regulate herbivore populations through bottom-up mechanisms, by influencing host availability, and top-down mechanisms, by enhancing natural enemies. Different trap cropping systemsincluding conventional, dead-end, genetically modified, perimeter, sequential, multiple and push–pull approaches have been successfully implemented across agricultural and horticultural crops. Field studies demonstrate that trap cropping significantly reduces pest incidence, minimizes insecticide use, conserves beneficial organisms and improves crop yield. For instance, crops such as yellow rocket, marigold, sunflower, and Napier millet have been effectively used against Diamondback moth, Fruit borers, tarnished bugs, and stem borers, while intercropping cabbage with cowpea and oats reduced aphid populations. Trap cropping also has potential applications beyond insect management, including nematode, weed and disease control. Despite limitations such as species specificity, management costs and competition with the main crop, trap cropping represents a practical and environmentally responsible approach to integrated pest management. Its adoption promotes ecological balance, sustainable crop production and organic farming practices. Future research should focus on region-specific crop-pest-trap crop models, climate-resilient varieties, cost-benefit analysis and farmer training to maximize its efficiency and adoption.

Keywords: Trap cropping, habitat manipulation, types of trap crops, integrated pest management (IPM)

Introduction
Insect-pests cause substantial yield and economic losses in crops worldwide. The average yield losses due to insect pests in India range from 25% to 30% in the case of major crops, such as rice, maize, cotton, and pulses (Dhaliwal *et al*., 2010) [8]. Farmers predominantly rely on pesticides for controlling insect pests. They lack knowledge regarding the judicious use of chemicals and their use has become a necessity to fulfill the growing food needs of the world population (Midega *et al*., 2015) [18]. However, the intensive and indiscriminate use led to the development of pest resistance, pest resurgence, secondary pest outbreaks and adverse effects on human health as well as the non-target organisms in the environment (Sharma *et al*., 2010) [24]. Use of large amounts of pesticides to boost crop yields has led to severe environmental damage and increased economic costs, highlighting the need for sustainable pest management alternatives.

Concept of trap cropping
IPM is a sustainable pest management strategy that utilizes all available techniques in a compatible manner to manage the pest population below ETL. Cultural control is a traditional tool and is a preventive pest management method that includes crop rotation, use of resistant cultivars, tillage practices, time of sowing, etc. Trap cropping is a highly effective cultural pest control method as it attracts pests away from the main crop, reducing crop losses by concentrating pests in a specific area (Shimada *et al*., 2021) [26].
The establishment of pest, its survival, development and spread are multidimensional interactions that depend on the host plant, environment and pest itself. The basic difference between sole crop and trap crops can be summarised from the herbivore point of view as host

quality and abiotic environmental factors of the concerned crop field. Considering the resource concentration and enemy hypothesis, the need for diversification of crops can be realised to minimise the pest incidence and intensify the natural enemy effects. The top-dow and bottom-up approaches can be explained to describe the beneficial role of trap cropping. There are 3 trophic levels, such as host plants, herbivores and natural enemies, which comprise the first, second and third trophic levels, respectively. Any alteration in the trophic level structure by changing the species richness and species diversity can lead to a change in herbivore composition in the crop microclimate.

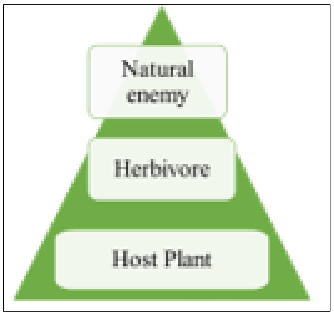

Fig 1: Top down approach

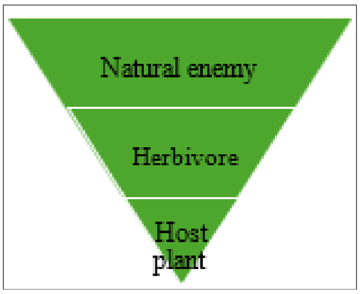

Fig 2: Bottom up approach

The host plant selection process by insect herbivores is regulated in 5 different steps, such as host habitat finding, host finding, host recognition, host acceptance and host suitability. Different non-host plants that divert insects from the primary crops can be planted to change the host plant-insect interaction process. Trap cropping may be advantageous in this sense. According to the enemy hypothesis, trap crops may function as an enemy host by impeding an insect's life cycle, among other obstacles. Thus, insect pests can be controlled in an environmentally responsible way by just changing the type of planting (Samal and Sahu, 2020) [23].

To enhance the predictability and dependability of the diversification strategy, it is essential to comprehend the mechanisms that drive herbivore population responses to diversified agro-ecosystems. Behavioral aspects that affected the spatial dynamics of herbivore populations included colonization patterns, movement speed, and the sensory methods used to locate host plants. Simulations indicated that the degree to which trap crops inhibit flight is the key parameter to manipulate the spatial dynamics of insects exhibiting postalighting host recognition behavior. For herbivore species that use olfactory or visual cues to find host plants, the mechanism of aggregation in the trap crop is a combination of attraction and arrestment and hence the population regulatory effect of the trap crop is higher compared to herbivores with post-alighting host recognition behaviour. An important factor that influences the efficacy of the disruptive cropping strategy is the strength of the emigrationinducing effect of the vegetation (Potting *et al*., 2005a) [20].

Selection and implementation of trap crops

The success of trap crop implementation hinges on careful selection and strategic placement. When choosing trap crops, several factors should be considered: 1) Pest preference: Research into the preferred host plants of the pests can guide the selection process. 2) Visual and olfactory cues: Certain colours and odours are more attractive to specific pests. Understanding the sensory preferences of pests can help in selecting the right trap crops. 3) Growth rate: Trap crops should have a growth rate that complements that of the main crop. This ensures that the trap crop is available and attractive to pests during the critical growth stages of the main crop. 4)Suitable location: Trap crops should be strategically placed at the edges of the main crop field or intercropped within the field. This placement maximizes their effectiveness in diverting pests away from the main crop. Adeoti *et al.* (2025) [2] at Abeokuta, Nigeria conducted the experiment on five amaranth mixing arrangements: middle, border, cluster, scatter, and no-amaranth (sole cucumber). All four spatial arrangements tested significantly reduced *Alocofera foveicollis* and *Epilachna chrysomelina* densities on the two cucumber varieties (Marketmore and Poinsett) with border and cluster designs showing the highest reduction in pest numbers. The amaranth plants in border and cluster arrangements were also found to trap higher pest numbers than other arrangements tested and therefore emerged as the optimal strategy in cucumber pest management. 5) Timely management: Regular monitoring and maintenance of trap crops are essential. If the trap crop becomes heavily infested, it may need to be removed and replaced to continue effectively diverting pests.

Factors determining the success of trap cropping systems

The potential success of a trap cropping system depends on the interaction of the characteristics of the trap crop and its deployment with the ecology and behaviour of the targeted insect pest. The most important insect characteristics are the insect stage targeted by the trap crop and the insect's ability to direct its movement, its migratory behaviour and its host-finding behaviour. To select a successful trap crop in the first case requires knowledge of the ovipositional preference; in the second case, knowledge of adult feeding preference is required. In general, the attractiveness of the trap crop and the proportion of trap crops in the field are important factors. The residency index, a measure of the time an organism spends between entering and leaving a unit area, is an important factor in managing an insect pest. A highly attractive trap crop is necessary to increase the residency index of an insect in an environment (Potting *et al*., 2005b) [20].

Types of trap crops

1. **Conventional trap crop:** Growing of more attractive crop in vicinity of the main crop. *e.g.*: Use of highly attractive varieties of squash to manage squash bugs and cucumber beetles in several cucurbitaceous crops (Anonymous, 2017) [4].

2. **Dead end trap crop:** It is highly attractive to insects but they or their offspring's can't survive. *e.g.*: Yellow rocket for Cabbage diamond back moth.

Lu *et al*. (2004) [16] at Hangzhou, China studied that *Plutella xylostella* L. adults were provided with a dual-choice of plants of *Barbera vulgaris* and Chinese cabbage in one arena, adult moths laid 2.5–6.8 times more eggs on the former than on the later. Nearly all individuals on plants of *B. vulgaris* died as neonates or early instar larvae, while 87–100% of the larvae on Chinese cabbage survived to pupation. The results demonstrated that *B. vulgaris* has a great potential as a dead-end trap crop for improving management of DBM.

3. Genetically modified trap crops: Certain crops having genetically modified traits towards insect resistance can be deployed to control the pest population. *eg.*: *Bacillus thuringiensis* Berliner (*Bt*) potatoes have been used as trap crops to manage colorado potato beetle (Balasko *et al*., 2020) [5].
He *et al*. (2021) [11] conducted laboratory experiments in Henan, China, to examine the ovipositional preference of FAW on both Bt-transgenic maize and non-transgenic maize. Their findings indicated that female moths showed a preference for egg laying on maize, with no notable difference in preference between conventional and *Bt* maize. However, when conventional and transgenic maize were infested with FAW larvae and subsequently damaged, the oviposition rate was significantly greater on the transgenic maize compared to the conventional one. The density of larvae and the amount of damage caused to conventional maize were considerably higher than those observed on *Bt* maize. Therefore, maize serves as a highly attractive and suitable host for both feeding and ovipositing and *Bt* maize could effectively function as a trap crop to safeguard other crops.

Deployment of trap crops

1. **Perimeter trap cropping:** Trap crops are planted around the borders of the main crop. *eg*: Perimeter trap crop with *Crotalaria juncea* in tobacco fields helps in conservation of natural enemies on all growth stages of tobacco. *Rhynocoris spp. is* known to be an important predator that has a broad host range of prey, including tobacco pests *Heliothis armigera, Spodoptera litura, etc* (Trisnawati and Azis, 2017) [29].
2. **Sequential trap cropping:** Trap crops are planted earlier or later than the maincrop to attract the pest. Bensen and Temple (2008) [7] at Yolo County, U.S. A. studied the mean population of the western tarnished plant bug across different planting dates and habitats. For the early planting, the mean *Lygus hesperus* population was consistently higher in the trap crop rows compared to cowpea across all sampling dates, with the highest value (6.49 ± 0.41^a) observed on 1st H August. These results indicate that trap cropping effectively attracted more *L. hesperus* individuals than cowpea alone.
3. **Multiple trap cropping:** Planting multiple trap crop species simultaneously to manage several insect pests or to enhance control of a single pest by combining attractive plants. Gordon *et al*. (2017) [9] at Leon County, U.S.A studied that the *Nezara viridula* preferred sorghum and sunflower, whereas *Euschistus servus* preferred sunflower followed by sorghum. So, the use of multiple crops like sorghum and sunflower helps to control these stink bugs. Food quality is important in trap crops because it is necessary to provide a continuous source of high-quality food embedded in the trap crops to prevent the buildup of *N. viridula* in the cash crop, which at some point will be very favourable for stink bug feeding. Thus, the reason why trap crops require multiple plant species is to maintain a competitive food source to outcompete and lessen the incidence of stink bugs on the cash crop.
4. **Push-Pull trap cropping:** The trap crop attracts the insect pest and combined with the repellent intercrop, diverts the insect pest away from the main crop. Maize stem borer is repelled by 4, 8-dimethyl-1,3,7-nonatriene released by Desmodium. Napier grass releases volatile organic compounds like octanal, nonanal, naphthalene, 4-allylanisole, eugenol and linalool, which attract female moths to lay eggs. In this way, stem borer can be controlled (Yadav *et al*., 2025) [33].

Increasing the effectiveness of trap crops

1. **Biological control-assisted trap cropping:** Trap crops can also reduce insect pest populations by enhancing populations of natural enemies. *e.g*., Sorghum trap crop used to manage cotton bollworm, *Helicoverpa armigera* (Hubner), also increases rates of parasitism by *Trichogramma chilonis* (Virk *et al.*, 2004) [31].
2. **Semio-chemically assisted trap cropping:** Trap crops whose attractiveness is enhanced by the application of semiochemicals or regular crops that can act as trap crops after the application of semiochemicals. *e.g.*: The trap crop was combined with semiochemical traps to enhance the trap crop's attractiveness for broad bean beetles and to trap and kill the beetles so that they do not disperse into the main crop. Two kairamonal attractants were used: one with faba bean flower and one with faba bean pod scent. The flower scent was composed of (R)- linalool (94%), cinnamyl alcohol (2%) and cinnamaldehyde (4%). The pod scent was composed of cis3-hexenyl acetate (30–40%), ocimene (15–20%), linalool (10–20%), beta- caryophyllene (10–20%) and limonene (15–20%). These attracted bean beetles, which prevent diversion into the main field (Raderschall *et al.*, 2025) [22].

Trap crops used for pest management

Perez *et al.* (2004) [19] at Geneva, New York reported that *Plutella xylostella* females laid significantly more eggs on Indian mustard, yellow rocket and glossy collards than on cabbage, while oviposition on waxy collards did not differ significantly from cabbage. In both Geneva and Camilla populations, adults showed a significant first-choice preference for volatiles of Indian mustard and yellow rocket over cabbage, a nearly significant preference for glossy collards and no significant preference for waxy collards. Larval survival was highest on Indian mustard (24.4%), though not significantly different from cabbage (22.2%) or waxy collards (18.9%) and was lowest on yellow rocket (0%), which did not differ significantly from glossy collards (6.7%). Development time from egg to pupation varied significantly among hosts, with pupation occurring earliest on Indian mustard, while no larvae reached pupation on yellow rocket confirming that it act as a dead-end trap crop.

Hussain and Bilal (2007) [15] at Shalimar, Srinagar studied that trapping of Helicoverpa larvae was highest in 3:1 combination of tomato and marigold which reduced percent fruit damage, followed by 6:1, 9:1, 12:1, 15:1.

Lu *et al*. (2008) [17] at Langfang, China conducted an experiment and studied that *Apolygus lucorum* densities on cotton with mungbean strips were significantly lower than in cotton without mungbean throughout the sampling period.

Hari and Jindal (2009) [10] at Ludhiana, Punjab conducted dual choice tests and studied that Napier millet hybrids were preferred for oviposition by chilo partellus when compared with maize or sorghum. These hybrids received about five times more eggs than maize. Significantly higher number of egg batches and total number of eggs were laid on Napier millet hybrid PBN 83 than on maize. Larval survival on Napier millet hybrids over a 30-day period indicated that greater mortality (approximately 60%) occurred within the first five days after egg hatching. None of the larvae survived to pupation in case of Napier millet hybrids. In maize, 28% of the initially introduced larvae reached pupation. The larvae reared on Napier millet plants were weak and larval weight was significantly less than those reared on maize.

Hormchan *et al*. (2009) [12] at Kanchanaburi, Tamil Nadu studied that the population of leafhopper were recorded from top and bottom leaves 30, 60 and 75 DAP (days after planting) and expressed as an average number / 2 leaves. The plots with trap crops were found to decrease in a number of leafhopper while yields increased comparing to the sole cotton in every variety/line.

Zhou *et al*. (2010) [35] at Guangxi, China studied the population densities of *Spodoptera litura* larvae which was highest in tobacco during March and April, when crops were in the seedling stage. In May and June, when crops were rapidly growing, their relative attractiveness changed. In May, *S. litura* oviposition preference was taro > tobacco > all other crops, whereas in June it was taro > tobacco. Rates of *S. litura* parasitism by *Microplitis prodeniae* and *Campoletis chlorideae* differed significantly among the six crops. Larvae suffered higher rates of parasitism by *M. prodeniae* and

C. chlorideae on taro plants than on other crops. This was due to density dependent and the higher densities of *S. litura* on taro than on other crops.

Baloch *et al*. (2016) [6] at Kunri, Pakistan studied the effect of trap crop on pest population in chilli agro-ecosystem using Chilli + Maize, Chilli + Sunflower and Chilli + Pea systems and the results were compared with chilli which was sown as sole crop. Weekly jassids, aphids, thrips, whiteflies and mealybugs population on chillies accompanied by maize as trap crop was lowest followed by sunflower and Pea.

Adebola *et al*. (2016) at Lapai, Nigeria studied the use of trap cropping system in the control of insect pest of okra by using cowpea and Roselle as the trapping plants. The relative abundance of aphid, leaf hopper, flea and cotton stainer increased from 5th to 7th Week and decreased at 9th Week. When trapped between roselle, it constantly reducing the pest population followed by roselle and cowpea. The highest number of fruits (13.66+ 0.88) was harvested from the okra trapped between roselle and roselle (TRR) and the number of fruits (7.59+ 0.87) harvested from okra trapped between cowpea and roselle (TCR) was not significantly different from control (8.00+ 0.57).

Akotsen *et al*. (2017) [3] at Alabama, U. S. A studied potential trap crops for season-long management of leaffooted bugs and stink bugs in peaches and concluded that wheat was the most attractive of all crop species evaluated in winter, whereas sunflower was found to be a highly attractive summer trap crop, followed by grain sorghum and pearl millet. Seasonal average densities of all leaf footed and stink bug species were 2 to 3.5 fold higher on wheat than other winter trap crops and 0.5 to 10 fold higher on sunflower than other summer trap crops. Overall, rye and wheat together provided a 4-week attraction period that coincides with the period of early migration (mid-March to April) of overwintering populations of leaf footed and stink bugs. Similarly, grain sorghum and sunflower together provided a 6-week attraction period (mid-July to August) for late season populations that may move into peaches from other adjacent crops.

Siddiqui *et al*. (2018) [27] at Tando Jam, Pakistan studied the effect of trap crops on population reduction of jassids, thrips and white fly in cotton intercropped with millet, maize and sunflower. The minimum population of jassids (0.89), whitefles (0.36) and thrips (6.20) was recorded on cotton intercropped with maize. The maximum population of predator, *Orius spp* was recorded on cotton intercropped with maize as (2.29) and (2.36) and *Geocoris ochropterus* (0.57) and (0.66) predators. This indicated that maize intercropped with cotton as trap crop resulted in the lowest density of pests and highest population of predators per plant.

Tomaseto *et al*. (2019) [28] at Sao Paulo, Brazil conducted 4-arm olfactometer assays, results indicated that females spent more time on orange jasmine than on the clean air fields. However, no significant effect was observed on the female foraging activity to the ‘Pera’ sweet orange vs. clean air. To further investigate orange jasmine trap crop effect on psyllid settlement and dispersal, adult psyllids were marked with different colours of fluorescent powder and released near the experimental sweet orange orchard with and without trap crop plots. Trap crop plots showed a significant reduction in the number of psyllids that settled on citrus trees compared to control plots at 1, 3 and 7 days after release.

Zhang *et al*. (2020) [34] at Xinjiang, China conducted an experiment and observed that *Lygus pratensis* population levels were markedly lower in cotton fields with sunflower borders. More specifically, significant differences were recorded between fields with and without sunflower strips for population levels of nymphs and adults.

Wang *et al.* (2021) [32] at Xinjiang, China conducted Y-tube olfactometer assays showed that *Lygus pratensis* adults were significantly more attracted to the volatiles from safflower and cotton than to pure air. Furthermore 72% of male adults and 68% of female adults choose safflower in the safflower *vs* pure air test and 63% of male adults and 60% of female adults choose cotton in the cotton *vs* pure air test. In the safflower *vs cotton* test, males and females showed a significant preference for safflower over cotton (females: $P < 0.001$) and 81% of male adults and 78% of female adults choose safflower. Population levels of *L. pratensis* adults and nymphs on the three patterns of trap crops were significantly affected by sowing patterns. Mean densities per m^2 of *L. pratensis* adults and nymphs on interplanting trap crops (adults: 41.70 ± 0.59 m–2; nymphs: 15.41 ± 0.86 m–2) were significantly higher than on ‘spot’ trap crops (adults: 34.35 ± 1.35 m–2; nymphs: 11.29 ± 0.70 m–2) and peripheral trap crops.

Hossain *et al.* (2022) [14] at Bogura, Bangladesh evaluated the effectiveness of trap cropping of Marigold, Carrot, Tomato and French bean with onion for the management of onion thrips. Onion protected by trap cropping with marigold, carrot and tomato significantly reduced thrips population up to 58.97%, 52.42% and 48.84%, respectively, but French bean had no significant effect. The maximum onion bulb yield of 15.24 t/ha was obtained in onion protected by trap cropping with marigold followed by carrot (13.48 t/ha) and tomato (12.62t/ha), whereas minimum bulb yield was registered in sole onion crop (10.60 t/ha). This study showed that marigold or carrot trap crop should be planted within onions to reduce the population of thrips from onion, thus lowered the damage to onion.

Scientists at Anand conducted two years experiment on influence of habitat manipulation on incidence and severity of pest damage in cabbage and observed that aphids population was lowest in T_1 (Cabbage intercropped with mustard and cowpea (5:1:1 rows) (7.40/ plant), followed by T_2 (Cabbage intercropped with mustard (5:1 rows) and oats as border crop (11.61/ plant)) and T_3 (Cabbage intercropped with cowpea (5:1 rows) and oats as border crop (11.82/ plant). All these three treatments were found to be statistically at par with each other. The highest population of aphids was documented in the treatment T_6 (Cabbage as sole crop (21.03/ plant). With regard to larval population of DBM, the recommended check treatment T_5 (Cabbage with cress as border crop) recorded the lowest population (2.06/plant) and it was statistically comparable to the treatments T_3 (2.19/plant), which was followed by the treatments T_2 (3.91/plant) and T_1 (3.99/plant). The highest DBM population of 8.50/plant was recorded in the sole cabbage. T_1, T_2 and T_3 showed reduced aphid population due to the presence of more coccinellids/plant as a result of the intercrops, mustard and cowpea, which served as aphid trap crops (Anonymous, 2023) [4].

Among all the treatments, the treatment T_3 had the highest equivalent yield (264 q/ha) and it recorded the highest net income of Rs. 215730 with ICBR of 1:4.49, followed by T_2 with the net income of Rs. 168006 with ICBR 1:4.04.

Recommendation proposed for farming community: Farmers of Gujarat growing cabbage under organic and natural farming are recommended to grow cabbage with vegetable cowpea as intercrop (5:1 rows) and one row of fodder oats as border crop to manage the population of aphids and diamond back moth (DBM), which enhances the natural enemies of insect pests infesting cabbage.

Hossain *et al.* (2024) [13] at Bogura, Bangladesh conducted an experiment by using various intercrops among them, chilli intercropped with garlic and carrot performed well, recording the lowest population of sucking pests, leaf curl index, larval population of *Helicoverpa armigera* and *Spodoptera litura*, as well as reduced fruit damage. In contrast, the highest pest population of aphids, thrips, mite and leaf curl index, larval population of *H. armigera* and *S. litura* and fruit damage were observed in the sole chilli crop. Mean yield data revealed that chilli intercropped with garlic yielded the highest red ripe chilli with 11.70 t/ha.

Additional uses of trap crops

Trap crop used as nematode management

- Oil radish and mustard used as a trap crops for (SBCN) sugar beet cyst nematode
- Sesbania, safflower, marigold and sunhemp are trap crops for jute root knot nematode

Trap crop used as disease management

- Brinjal, cucumber and okra are trap crops for (TYLCV) tomato yellow leaf curl virus.

Trap crop used as a weed management

The effects of trap crops on parasitic weed plays a great role in stimulating seed germination. Stimulation of suicidal germination of striga seeds by non- host cultivars (Prakasha *et al*., 2016) [21].

Advantages

- Minimize the use of pesticidesSuitable for commercial and non-commercial crop production
- Safe for the environment and natural enemies
- Improves the crop quality
- Suitable for organic and natural farming

Disadvantages

- Relatively species specific
- Limit the practical use in large scale
- Expense of producing and destroying crop that brings “NO INCOME”
- Competition with the main crop for resources

Conclusion

Trap cropping is an effective and eco-friendly strategy in integrated pest management. By planting specific crops that attract pests away from the main crop, reduce pest pressure and minimize the use of insecticides. However, successful implementation of trap crops in agricultural and horticultural ecosystems *i.e*., yellow rocket for diamondback moth, marigold for fruit borer, sunflower and safflower for tarnished bug, cabbage intercropped with cowpea and oats as a border crop for aphids and DBM *etc*. Thus, trap crops can play a vital role in pest management and promotes ecological balance in agriculture.

Future thrusts

Need to

- develop crop-pest-trap crop models tailored to specific regions and pests
- develop climate-resilient varieties
- analyze cost–benefit ratio
- conduct farmer training and awareness programme

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