

Effect of Buckwheat Farmscapes on Abundance and Parasitism of *Pieris rapae* (L.) in Virginia Collards¹

C. R. Philips², T. P. Kuhar and D. A. Herbert

Department of Entomology, 216 Price Hall, Virginia Tech, Blacksburg, Virginia 24061-0319 USA

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Abstract Buckwheat, *Fagopyrum esculentum* Moench, with its abundant nectaries and long bloom period is often planted on vegetable farms, vineyards, and orchards to supply nectar and pollen to attract and conserve natural enemies. However, scientific data demonstrating the actual biological control benefit of such companion plantings are scarce. The objective of this experiment was to determine the effect of flowering buckwheat on the abundance and parasitism of imported cabbageworm, *Pieris rapae* (L.), in collards, *Brassica oleracea* L. var. *acephala* DC. In 2012 and 2013, buckwheat was planted in the center of 4 spatially-isolated 150 × 8 m collard fields. Lepidopteran pest abundance and larval parasitism were compared at distances of 1, 15, 30, 45, and 60 m from the buckwheat. *Pieris rapae* (L.) was the predominant lepidopteran pest species comprising over 90% of the total larvae observed on collards. No differences were detected in the abundance or parasitism of *P. rapae* larvae with increasing distance from buckwheat companion plantings, with parasitism averaging 68% (± 1.82) across all plots and years. Although the buckwheat companion planting did not appear to have a significant effect on *Pieris* populations in collards, several predatory arthropod species, including anthocorids, syrphids, and cantharids were collected in high numbers from the flowering buckwheat. The population dynamics and movement of these beneficial species from the buckwheat into adjacent cash crops should be investigated in future studies.

Key Words farmscaping, *Pieris rapae*, *Brassica oleracea*, buckwheat, conservations biological control

Buckwheat, *Fagopyrum esculentum* Moench, has been widely used as a companion planting on vegetable farms (Lavandero et al. 2005, Lee and Heimpel 2005), vineyards (Scarratt et al. 2008), and orchards (Stephens et al. 1998) to supply nectar and pollen to attract arthropod natural enemy populations. However, scientific data demonstrating the true biological control benefit of such companion plantings are scarce. A better understanding of how buckwheat companion plantings impact natural enemy abundance and determining if this translates to increases in natural enemy movement and pest suppression in adjacent crops is needed.

Natural enemies have a tremendous capacity to regulate lepidopteran pest populations and, over the past several decades, numerous studies have greatly increased our understanding of how parasitoids forage for hosts (Vinson 1976,

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²Address inquiries (email: chris.philips@wsu.edu). Current address: Department of Entomology, 166 FSHN Bldg., Washington State University, Pullman, WA. 99164.

Lewis et al. 1990, Vet and Dicke 1992, Tumlinson et al. 1993, De Moraes and Lewis 1999, Wäckers et al. 2007, Winkler et al. 2010). However, the availability of adult food sources also can impact parasitoids, and how they balance their time between these two behaviors is not well understood. Even more ambiguous is the impact that farmscaping has on these behaviors and the role predators play in lepidopteran pest control.

Farmscaping refers to the arrangement or configuration of plants that promotes biological pest management by attracting and sustaining beneficial organisms (Bugg and Pickett 1998). Studies have shown that floral resources can increase the abundance, longevity, and fecundity of various adult predators and parasitoids (Wratten et al. 2003, Eubanks and Styrsky 2005, Woltz et al. 2012). However, they may also provide resources for pest populations.

In southwest Virginia, imported cabbageworm, *Pieris rapae* (L.), is the predominant lepidopteran pest of brassica crops such as collards, *Brassica oleracea* L. var. *acephala* DC, and is known to feed on nectar as an adult (Latheef and Irwin 1979, Lasota and Kok 1989, Zhao et al. 1992, Philips 2013). This has been reported to result in increases in larval abundance and feeding damage in crops adjacent to flowering plants (Latheef and Irwin 1979, Zhao et al. 1992). Moreover, both pests and beneficials have been shown to aggregate around nectar sources if these resources are limiting in the field (Wäckers et al. 2007).

Cotesia glomerata (L.) was introduced to the United States as a biological control agent against *P. rapae* in 1884 (Clausen 1978). The species became well established in the U.S. and is currently the primary parasitoid of imported cabbageworm in Virginia (Herlihy et al. 2012). Because this species of parasitoid is synovigenic, adult feeding is necessary to meet the nutritional requirements necessary for females to produce eggs and successfully reproduce (Harvey et al. 2003, Herlihy et al. 2012). Adults are commonly observed feeding on flowers, but because females must continue to feed to produce eggs, how they move from these resources is largely unknown (Wäckers and Van Rijn 2005, Winkler et al. 2010). However, this increase in parasitoid abundance does not necessarily translate to increased pest suppression (Heimpel and Jervis 2005).

Cotesia glomerata is a gregarious endoparasitoid that parasitizes first instars and emerge at the end of the fifth instar. Because of this timing, larvae will continue to feed throughout development, and research has shown that larvae parasitized by *C. glomerata* will consume significantly more leaf tissue than unparasitized larvae (Rahman 1970). This indicates that overall increases in parasitism will likely lead to an increased damage in the early generations, it should lead to lower levels of pest pressure in future generations. Given this inimitable parasitoid-host relationship and that both *P. rapae* and *C. glomerata* are known to feed on nectar, this presents a unique opportunity to investigate this anomaly and how farmscaping may impact these interactions. Therefore, the goal of this experiment was not to determine if parasitism by *C. glomerata* leads to increased feeding, as this was assumed based on the results of Rahman (1970), but rather to determine if there is an increase in *P. rapae* abundance and parasitism around buckwheat farmscapes. Herein, we report the results of a 2-yr experiment conducted in Virginia that evaluated the effect of buckwheat farmscapes on the abundance of and parasitism of *P. rapae* larvae by *C. glomerata*. In addition, the natural enemy communities associated with buckwheat farmscapes in brassica systems were determined.

Materials and Methods

Study system. Collards were used for this experiment because they are a known host of *P. rapae* and harbors a rich diversity of natural enemies (Chamberlin and Kok 1986, Lasota and Kok 1986, 1989, Gaines and Kok 1995, Cordero 2005, Cordero et al. 2007). In addition, collards are a staple crucifer crop in the South and are particularly vulnerable to economic losses from lepidopteran pests because the leaves, which are fed upon by pests, are the marketable portion of the crop.

Experiments were conducted in 2012 and 2013 near Blacksburg, VA, at the Virginia Tech Kentland Research Farm (80°25'W, 37°14'N). Four spatially-isolated 150 × 8 m blocks (=replicates) of collards were established in each yr. Sixteen rows of collards (var. Champion) were direct seeded on 2 May 2012 and 20 rows (6 var. Champion and 14 var. Georgia) were seeded on 23 Apr 2013. Sixteen 7-m rows of buckwheat were direct-seeded at the same time as the collard in the center of each field leaving 60 m of collards on each side (Fig. 1). On 15 May 2013 collards and buckwheat were reseeded because of poor stand establishment. Fields were separated by a minimum of 150 m and were isolated from other flowering vegetation. At 1, 15, 30, 45, and 60 m from buckwheat farmscapes, we visually inspected 10 collard plants each wk beginning 30 d after planting and recorded the total number of all lepidopteran larvae until harvest (approx. 30 d). In 2012, visual counts were performed on 4, 11, 18 and 25 June. In 2013, counts were performed on 10, 17, and 24 June and 1 July.

Parasitoid abundance was evaluated in each block at each distance from the buckwheat using a single 10 × 15 cm yellow sticky trap (Olson, Medina, OH) placed just above the collard canopy. Sampling began 30 d after planting, and traps were replaced weekly until harvest (approx. 30 d). In 2012, traps were collected on 11, 18 and 25 June. In 2013, traps were collected on 17 and 24 June and 1 July. Sticky traps were evaluated under a stereomicroscope, and all parasitoids were counted and identified to the lowest taxonomic group possible.

On 11 and 28 June in 2012, and on 20 June 2013 a sample of 5 various stage *P. rapae* larvae were collected in each of the 4 blocks at each distance in both directions from the buckwheat for a total of 50 per block and a total of 200 larvae per sample. The number of larvae collected varied because of low populations. Larvae were returned to the laboratory and were held in Petri dishes with a collard leaf disk to assess parasitism. Larvae were monitored until parasitoids emerged, successful pupation occurred, or the larvae died of other causes. Larvae collected from the same distance

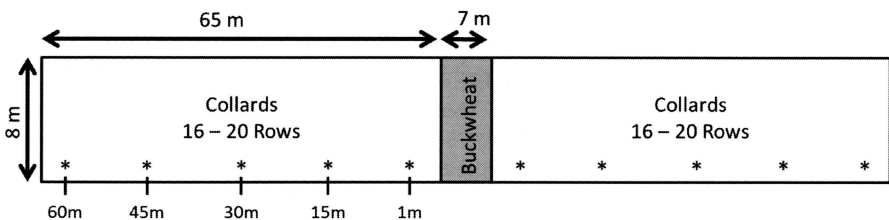


Fig. 1. Diagram of collard plot with buckwheat farmscape used to sample insects in 2012 and 2013. Sample distances are denoted by *.

in each block were combined, and percent parasitism was recorded as the total number of larvae parasitized from the total collected on a given date.

A single 10-sec vacuum sample was collected on 8 rows of buckwheat (2 in each plot) during peak bloom on 5 June and 25 September 2012, and 12 and 24 June 2013 using a motorized suction sampler (Craftsman™ 200 mph leaf blower-vac) fitted with a fine mesh 19 L paint strainer bag on a 12-cm diam. intake tube. In 2013, both samples were collected in June because there was not a fall collard planting. Samples were returned to the laboratory, placed in a freezer for 24 h, and insects were sorted and identified to lowest taxonomic group possible. Abundance of all collected predators was recorded.

Data analysis. Data from all experiments were analyzed in JMP Pro 10 (JMP 2013). Regression analysis was used to determine any relationship between distance from flowering buckwheat farmscapes and lepidopteran larval density, numbers of various natural enemies caught on yellow sticky cards, and percent parasitism of *P. rapae* larvae.

Results

Lepidopteran pest abundance. Overall, the proximity to buckwheat had no significant effect on the density of *P. rapae* larvae in collards ($R^2 = 0.001$, $P = 0.56$, $Y = 0.002X + 1.42$; Fig. 2). In 2012, 364 lepidopteran larvae were observed with *P. rapae* being the most abundant (Table 1). The only other species observed was cross-striped cabbageworm, *Evergestis rimosalis* (Guenee); and no significant differences were detected in abundance with distance from buckwheat ($R^2 < 0.001$, $P = 0.98$; Fig. 2). In 2013, 353 larvae were observed with *P. rapae* again being the most abundant throughout sampling; and no significant differences were detected ($R^2 = 0.008$, $P = 0.21$; Fig. 2).

Parasitoid abundance. On all sample dates, parasitoid numbers were very low on yellow sticky traps. Only 37 parasitoids were collected with 13 in 2012 and 24 in 2013. This suggests that yellow sticky traps may not be an adequate tool for monitoring parasitoids in collards.

Parasitism. Over the 3 collection dates, 431 larvae were collected with an average parasitism of 68% (± 1.82). No significant difference in parasitism with distance was detected ($R^2 = 0.005$, $P = 0.48$, $Y = 0.048X + 71.51$; Fig. 3). In 2012, two collections were made with parasitism rates of 70 (± 4.19) and 65% (± 1.79), and no significant differences were detected with distance from buckwheat ($R^2 = 0.007$, $P = 0.63$). In 2013, a single collection was made with parasitism rates of 68% (± 3.09), and again no significant difference was detected with distance from buckwheat ($R^2 = 0.002$, $P = 0.86$; Fig. 3).

Predator communities. In 2012, a total of 407 insects were collected, 296 in the spring and 112 in the fall. In the spring sample, 214 predators, 34 parasitoids, and 48 known pests were collected. In the fall, 22 predators, 8 parasitoids and 82 known pests were collected. In 2013, 339 insects were collected, 212 predators and parasitoids and 127 pests. In both years, almost all of the collected pests were tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvois).

Over the 4 sample periods, 7 families of insect predators were collected, the most abundant being anthocorids, syrphids, and cantharids. Braconids were the most abundant parasitoid, accounting for about half of the total parasitoids collected (Table 2). Relatively few significant agricultural pests were found on the buckwheat with the exception of *L. lineolaris* (Table 3).

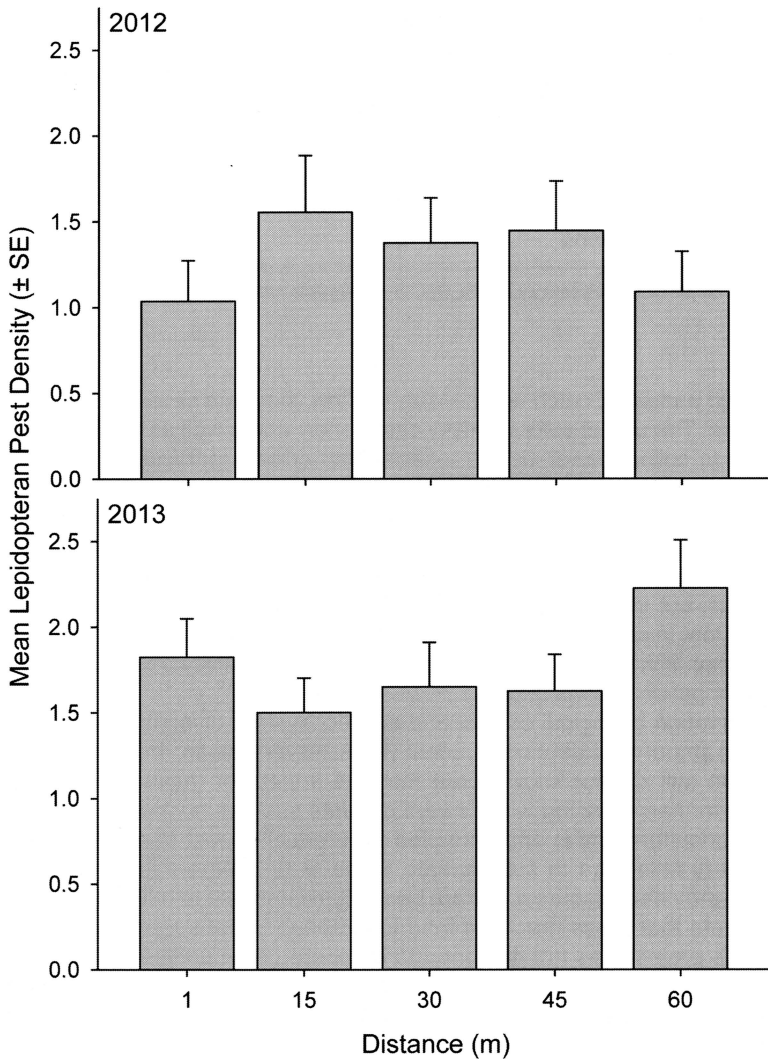


Fig. 2. Mean (\pm SE) density of lepidopteran larvae in collard at various distances from a central buckwheat companion planting at the Virginia Tech Kentland Research Farm in Blacksburg, VA in 2012 and 2013.

Discussion

In the current study, parasitism rates of *P. rapae* did not differ with distance from buckwheat. The average rates of parasitism were around 70% throughout the 120 m plots of collards. The catch of parasitoid adults on stickycards was low throughout the study, which indicates this sampling strategy may not be effective for monitoring parasitoids in collards.

Table 1. Lepidopteran larvae found on collards at the Virginia Tech Kentland Research Farm near Blacksburg, VA.

Total number of larvae observed				
Year	Period	ICW	DBM	CSCW
2012	Spring	359	0	5
2013	Spring	290	62	1

ICW = *Pieris rapae*; DBM = *Plutella xylostella*; CSCW = *Evergestis rimosalis*; CL = *Trichoplusia ni*.

Although parasitoid catch was consistently low, there are several reasons this may be the case. The use of colored sticky cards often works well as a passive sampling technique to collect flower-visiting insects. Trap color is particularly important, and attraction of insects to a particular color determines its effectiveness. These differences in preference may influence what species are collected in these samples (Brødsgaard 1989, Leong and Thorp 1999, Cho et al. 2011, Vrdoljak and Samways 2012). It is unknown if the primary parasitoids of lepidopteran pests in collards demonstrate color preferences, but this could be a reason why parasitoid abundance on yellow sticky cards was low. In addition, it has been suggested that the parasitoid *C. glomerata* may not be nectar-limited in the field and, thus, focus their activity on searching for larval hosts (Heimpel and Jervis 2005).

Conservation biological control and agroecosystem diversity have received an increasing amount of attention in recent years. Nevertheless, there is a tremendous amount we still do not know about the true impact of these practices on pest suppression. Farmscaping with flowering plants such as buckwheat is common in organic agriculture and is often credited with reducing pest populations. However, there is very little data to substantiate these claims. Whereas there is no doubt that plant-provided resources attract beneficial insects, it is difficult to find studies that illustrate that these practices lead to increased pest suppression in adjacent crops. This project was not designed to compare communities on fields with and without farmscapes; it was intended to illustrate what level of protection may be provided by a farmscape and how farmscapes influence *P. rapae* dynamics in a collard system.

Although most research to date has focused on insect populations at a single scale of land use, recently there has been an emphasis on scale, both spatial and temporal, as well as farmscape arrangement. It is also important to note that pest suppression is likely to be influenced by landscape diversity and that techniques such as farmscaping may be more important where regional landscapes are less diverse (Tscharntke et al. 2005, Schmidt et al. 2008, Zaller et al. 2008, Gardiner et al. 2009, O'Rourke et al. 2011, Tscharntke et al. 2012). Therefore, the ability of a grower to manipulate insect populations by farmscaping may depend on the regional landscape structure, so it is important to examine farm-level diversity in the context of regional landscape diversity. This is known as the intermediate landscape-complexity hypothesis, which states that local conservation management will have the greatest impact in structurally simple, rather than extremely simplified or complex landscapes (Tscharntke et al. 2012). In the current study, overall abundance of *P. rapae* did not

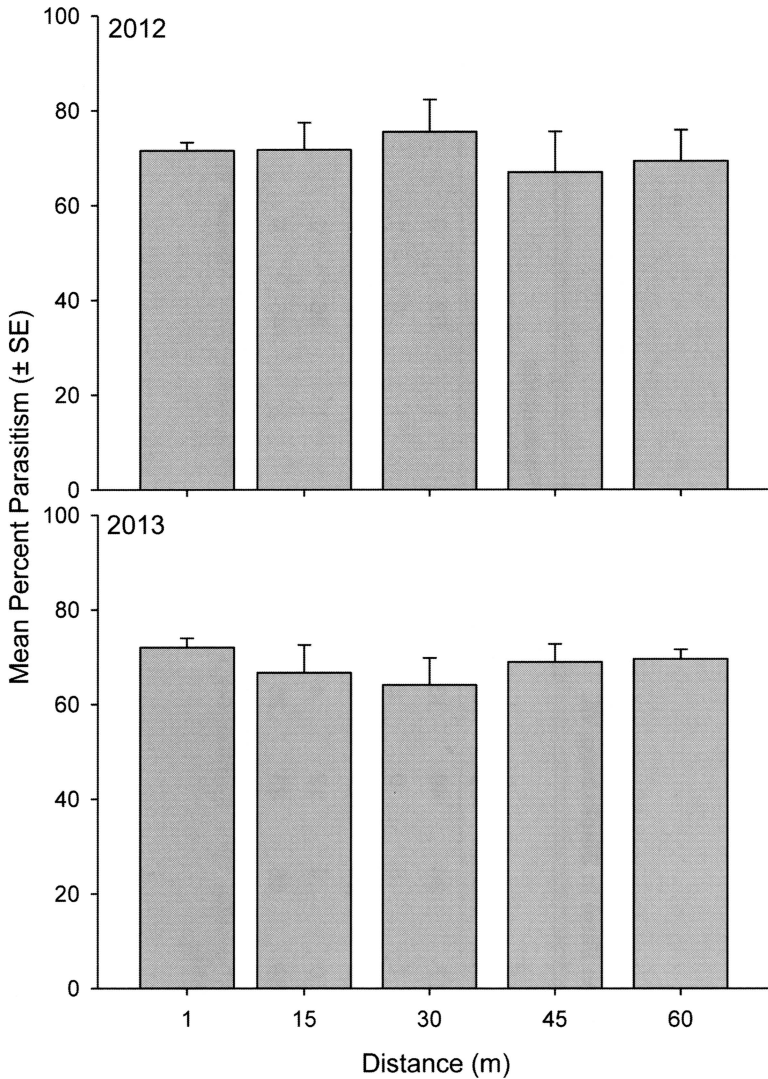


Fig. 3. Mean parasitism of *Pieris rapae* larvae by *Cotesia glomerata* in collard at various distances from a central buckwheat companion planting at the Virginia Tech Kentland Research Farm in Blacksburg, VA in 2012 and 2013.

vary with distance. Indicating that, in the midAtlantic, the nature of the landscape may be such that it provides enough of a natural farmscape making the need to replace crops with additional farmscaping unnecessary. Increasing the spatial scales at which these studies are conducted may lead to better predictions about the effects of diversity on insect populations.

Table 2. Predator and parasitoid abundance collected in vacuum sample of flowering buckwheat adjacent to collard at the Virginia Tech Kentland Research Farm in Blacksburg, VA.

Month	Day	Year	Period	Predators and Parasitoids											Total
				Brac	OHP	Syr	Coc	Can	Aran	Chr	Anth	Geo	Red		
6	5	2012	Spring	17	34	49	13	35	13	1	82	3	1	248	
9	25	2012	Fall	4	8	0	6	0	5	1	4	1	1	30	
6	12	2013	Spring	12	20	22	2	32	2	0	24	0	3	117	
6	24	2013	Spring	0	4	12	4	32	4	1	36	2	0	95	
Total				33	66	83	25	99	24	3	146	6	5	490	

Brac = Braconidae; OHP = Other Hymenopteran Parasitoids; Syr = Syrphidae; Coc = Coccinellidae; Can = Cantharidae; Aran = Araneae; Chr = Chrysopidae; Anth = Anthicoridae; Goe = Geocoridae; Red = Reduviidae.

Table 3. Pest abundance collected in vacuum samples of flowering buckwheat adjacent to collard at the Virginia Tech Kentland Research Farm in Blacksburg, VA.

Month	Day	Year	Period	Pests			Total
				<i>Lygus</i> <i>Spp.</i>	<i>Diabrotica</i> <i>undecimpunctata</i> <i>howardii</i>	<i>Pieris</i> <i>Rapae</i>	
6	5	2012	Spring	45	1	2	49
9	25	2012	Fall	78	2	1	84
6	12	2013	Spring	63	0	0	63
6	24	2013	Spring	63	1	0	64
Total				249	4	3	260

Another question that remains unanswered is the role that generalist predators play in pest suppression. Because certain generalist predators were highly abundant on the flowering buckwheat in these experiments, they may be playing a larger role in pest management where farmscaping is used than previously believed. For example, cantharid adults were one of the most abundant predators found on buckwheat; however, very little is known about the biology and ecology of these predators. Preliminary investigations show that the predominant species of cantharid found in these studies is a voracious predator and actively fed on numerous species of agriculture pests (CRP, unpubl. data). Future research will need to include investigating the biology, habitat use, and predation impacts of generalist predators, such as cantharids, as well as the impact of plant-provided resources and diversity on intraguild predation and predator-predator interactions.

It is also important to remember that whereas the primary goal of farmscapes is to attract and conserve beneficial insects, they may serve a number of other purposes as well. Farmscape plantings can be arranged in one or a combination of designs and farm sites: (1) as living mulches or trap crops near cash crops; (2) in fencerows or borders; (3) as island patches within rows or occupying entire rows spaced at regular intervals within the field; or (4) as herb/flower cash crops intercropped with vegetable/fruit crops. Some of these other practices, such as herbs and cut flowers, can add diversity as well as value to farming operations. Therefore, whereas there may not be obvious pest management advantages to farmscaping, other ecological or economic advantages may exist.

Farmscaping has tremendous potential in improving natural pest control and studies such as this help in improving our understanding of the ecology in these systems. However, we still need to increase our knowledge of how plant-provided resources impact natural enemy activity (Powell 1986, van Emden 1990, Heimpel and Jervis 2005). Future research will have to be aimed at improving our ability to unambiguously evaluate if, in fact, plant-provided resources lead to improved pest suppression and our understanding of the population dynamics and movement of beneficial species from the buckwheat into adjacent cash crops in different cropping systems.

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