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SYNTHESIS AND EVALUATION OF DIFFERENT PEST MANAGEMENT MODULES AGAINST VECTOR AND SUCKING PESTS OF BITTER GOURD

Sintesis dan Evaluasi Beberapa Modul Pengendalian Hama Terhadap Vektor dan Hama Pengisap Paria

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ABSTRACT

Bitter gourd, *Momordica charantia* Linn., is one of the most important traditional vegetable in India. Infestations of sucking pests especially jassid, and whitefly occurred thorough out the crop growth period in the region. For ecofriendly management, different pest management modules *viz*., bio-intensive, chemical, and integrated modules were evaluated against these sucking pests and compared under field conditions during 2019–2021. Among the three tested modules, the integrated pest management (IPM) comprised seed treatment with imidacloprid @ 5–10 g kg^{-1} of seed, installation of yellow sticky traps @ 25–30 ha^{-1}, border crop with maize, spraying of azadirachtin 1500 ppm @ 10 ml L^{-1}, thiamethoxam @ 1 g 3^{-1} L, imidacloprid @ 1 g 12^{-1} L, cyantraniliprole @ 1.8 ml L^{-1}, neem oil (0.5%) + *Lecanicillium lecanii* @ 2.5 g L^{-1}, and neem oil (0.5%) + *Beauveria bassiana* @ 2.5 g L^{-1} from 20 to 70 days after sowing at 10 days intervals each harboured lowest whiteflies population (0.63 per leaf) with maximum per cent reduction over control of 70.14. The number of predatory lady bird beetles and polyphagous spiders were also higher. The highest healthy fruit yields (171, 179, and 153 q ha^{-1}) were recorded from the IPM module for three consecutive years (2019, 2020, and 2021, respectively). In terms of return, maximum net profit of ₹71,211 was obtained from the IPM module with the highest incremental cost-benefit ratio of 1:5.18. Therefore, the IPM module could be a viable ecofriendly option in the management of the sucking pests of bitter gourd, along with the conservation of natural enemies.

[Keywords: Bitter gourd, sucking pests, predators, pest management modules, economics]

ABSTRAK

Paria, Momordica charantia Linn*., merupakan salah satu sayuran tradisional terpenting di India. Hama pengisap terutama dari famili Jassidae dan kutu kebul menyerang paria sepanjang periode pertumbuhan tanaman. Beberapa modul pengendalian hama, yaitu modul pengendalian biointensif, kimia, dan integrasi berbagai komponen teknologi pengendalian dievaluasi efektifitasnya untuk mengendalikan hama pengisap pada kondisi lapangan dari 2019 hingga 2021. Di antara tiga modul yang diuji, modul pengendalian hama erpadu (PHT) integrasi dari perlakuan benih dengan imidakloprid @ 5–10 g kg^{-1} benih, dan pemasangan perangkap tempel kuning @ 25–30 ha^{-1}, tanaman pembatas dengan jagung, penyemprotan azadirachtin 1500 ppm @ 10 ml L^{-1}, thiametoksam @ 1 g 3^{-1} L, imidakloprid @ 1 g 12^{-1} L, siantranilifrol @ 1,8 ml L^{-1}, minyak nimba (0,5%) +* Lecanicillium lecanii *@ 2,5 g L^{-1}, dan minyak mimba (0,5%) +* Beauveria bassiana *@ 2,5 g L^{-1} dari 20 hingga 70 hari setelah tanam (HST) pada interval 10 hari, masing-masing ditemukan kepadatan populasi kutu kebul terendah (0,63 per daun) dengan maksimum pengurangan serangan 70,14% dibandingkan kontrol. Kepadatan populasi kumbang coccinelid dan predator polifag laba-laba juga lebih tinggi pada tanaman yang menerapkan modul ini. Hasil buah sehat tertinggi (171, 179, dan 153 kg ha^{-1}) diperoleh dari modul PHT selama tiga tahun berturut-turut, yakni 2019, 2020, dan 2021. Dalam hal penerimaan, laba bersih maksimum ₹71.211 diperoleh dari modul PHT dengan rasio biaya-manfaat tambahan tertinggi 1:5,18. Oleh karena itu, modul PHT menjadi pilihan rasional pengendalian hama pengisap paria yang ramah lingkungan dan dapat meng konservasi musuh alami.*

[Kata kunci: Paria, hama pengisap, predator, modul pengendalian hama, kelayakan ekonomi]

INTRODUCTION

Sucking pests are considered a serious problem in vegetable production. They suck the sap from the plants by their specially-adapted mouthparts and secret copious amount of sugar-rich sweet honeydews on the plant parts. Due to their feeding, affected plants lost their vitality and affected plant parts have symptoms like upwards cupping, curling, withering, browning, yellowing, and malformed depending on the host plants and damage severity. Due to their anal secretion, deposited honeydews on plant surfaces invite sooty-mould fungus and cause black sooty-mould. This further hinders the normal photosynthetic activity of the plants (Halder et al. 2015). Apart from sucking the sap and there by devitalizing the plants, many of them also serve as a vector in transmitting many viral diseases.

Bitter gourd (*Momordica charantia* L.: Cucurbitaceae), colloquially known as bitter melon; bitter apple; bitter squash; balsam-pear; *karela*, is cultivated throughout the world, especially in the tropical and sub-tropical areas (Kandangath et al. 2015). It is extensively grown throughout India occupying an area of 0.08 m ha with a production of 0.82 mt (NHB 2014). India is still far behind from many countries in terms of productivity, which is quite low owing to attack by several pests which are major constraints in realizing the productivity potential of bitter gourd (Halder et al. 2018). The crop is ravaged by several insect pests thorough out its growth period. Incidence of sucking pests is of paramount importance for healthy crop growth, sustainable production and productivity.

Amongst the sucking insect pests, whiteflies (*Bemisia tabaci* (Gennadius)) (Hemiptera: Aleyrodidae), leaf hoppers (*Amrasca biguttula biguttula* (Ishida)) (Hemiptera: Cicadellidae), and red spider mites (*Tetranychus urticae*) (Trombidiformes: Tetranychidae) are predominant. The incidence of leaf hoppers are dominant mainly in eastern and northern parts of the country covering Indian states like Uttar Pradesh, Bihar, Jharkhand, and West Bengal. An enigma, the whitefly, being polyphagous, is cosmopolitan in distribution and occurred almost thorough out the country. Moreover, the dreaded disease *bitter gourd yellow mosaic virus* (BGYMV) is vectored by whitefly (Rai et al. 2014). Incidence of red spider mite is observed during the prolonged summer season particularly in the month of April–May.

To control these nefarious pests of bitter gourd causing serious damage, Indian farmers often rely on the spraying of chemical pesticides. It is not unusual for the bitter gourd growers to give 20–25 chemical sprays in a season, which most of the time are unnecessary and unjustified furthermore without any appreciable increase in the yield (Roy et al. 2017; Halder et al. 2018). Faster control strategy against these pests and quest of getting higher yields, has led to indiscriminate, injudicious, unnecessary, and excessive use of chemical pesticides set about the problems like resistance to pesticides, resurgence of target sucking insects accompanied by secondary pest outbreak, residues problems in food and beverages, adverse effect on human health, and massive killing of non-target organisms (Halder et al. 2019, 2021).

Development of suitable integrated pest management (IPM) package for ecofriendly sucking pest management for sustainable bitter gourd production is the need of the hour. Moreover, information on the development of such modules for the holistic management of nefarious sucking pests in a wider area in bitter gourd is scanty. Numerous management strategies for the pests of bitter gourd crops have been developed, but these have mostly been dealt with in isolation, chemical based and individually, thus have met with little desired success (Roy et al. 2017). Several local farmers visiting the institute also reported the same problem. This prompted to synthesize and evaluate different pest management modules in order to identify the most economic one for sustainable and ecofriendly sucking pest management in bitter gourd. The integration of all the pest management strategies could reduce the application of harmful chemical pesticides to a greater extent.

MATERIALS AND METHODS

Study Area

The field experiments were carried out at the experimental farm of ICAR-Indian Institute Vegetable Research, Varanasi (82°52’ E longitude and 25°12’ N latitude), Uttar Pradesh, India during the summer seasons (May to September) for three consecutive years of 2019, 2020, and 2021. The experimental site comes under the alluvial zone of Indo-Gangetic plains having soils silt loam in texture and low in organic carbon (0.43%) and available nitrogen (185 kg ha^{-1}).

Raising of the Crops

To experiment, the field was prepared by deep ploughing and made into a fine tilth before seed sowing. Seeds of bitter gourd (cv. Kashi Mayuri) were sown by dibbling in the soil of 2–3 cm depth during second fortnight of May with spacing between plant to plant 60 cm and row to row 3 m in a large-sized plot of 15 m x 10 m for each module. As such four such plots (150 m^2 each) were prepared. From each plot, five fixed spots (5 m x 4 m each, four in corners, and one in the centre of the plot) were selected randomly considering one spot as one replication. Thus five replications were maintained for each module and a trailing system of cultivation was followed.

The recommended dose of N, P, K fertilizers and FYM 15–20 t ha^{-1} were applied. N, P, and K were supplied through urea, single super phosphate, and muriate of potash, respectively. Half of the nitrogen was applied at the time of sowing as basal dose and the rest half was equally split at the vine development stage and the flower initiation stage. The full doses of both phosphorus and potassium were given at the time of final land preparation. Hand weeding and irrigations were provided as required and usual crop husbandry measures were undertaken except plant protection measures.

Pest Management Modules

Different pest management modules *viz*., bio-intensive, chemical, and integrated modules were evaluated against these sucking pests and compared under field conditions in 2019–2021. Details of the modules or treatments are as follows.

Treatment 1: Bio-intensive pest management module (BIPM)

- Installation of yellow sticky traps @ 25–30 ha^{-1}
- Spraying of azadirachtin 300 ppm @ 10 ml L^{-1} at 20 days after sowing (DAS)
- Spraying of *Lecanicillium lecanii* @ 5 g L^{-1} at 30 DAS
- Spraying of *Beauveria bassiana* @ 5 g L^{-1} at 40 DAS
- Spraying of neem oil (0.5%) + *L. lecanii* @ 2.5 g L^{-1} at 50 DAS
- Spraying of neem oil (0.5%) + *B. bassiana* @ 2.5 g L^{-1} at 60 DAS
- Spraying of neem seed powder pellets @ 30 g L^{-1} at 70 DAS

Treatment 2: Chemical pest management module (CPM)

- Seed treatment with imidacloprid 48 FS @ 5–10 g kg^{-1} of seed
- Spraying of thiamethoxam 25 WG @ 1 g 3^{-1} L at 20 DAS
- Spraying of cyantraniliprole 10.26 OD @ 1.8 ml L^{-1} at 30 DAS
- Spraying of imidacloprid 70 WG @ 1 g 12 L^{-1} at 40 DAS onwards till 70 DAS at 10 days interval each

Treatment 3: Integrated pest management module (IPM)

- Seed treatment with midacloprid 48 FS @ 5–10 g kg^{-1} of seed
- Installation of yellow sticky traps @ 25–30 ha^{-1}
- Border crop with maize
- Spraying of azadirachtin 1500 ppm @ 10 ml L^{-1} at 20 DAS
- Spraying of thiamethoxam 25 WG @ 1 g 3^{-1} L at 30 DAS
- Spraying of imidacloprid 70 WG @ 1 g 12^{-1} L at 40 DAS
- Spraying of cyantraniliprole 10.26 OD @ 1.8 ml L^{-1} at 50 DAS
- Spraying of neem oil (0.5%) + *L. lecanii* @ 2.5 g L^{-1} at 60 DAS
- Spraying of neem oil (0.5%) + *B. bassiana* @ 2.5 g L^{-1} at 70 DAS

Treatment 4: Untreated control

In addition to these, some common general practices like installation of cue lure trap 25–30 per ha for all the treatments for the management of cucurbit fruit fly, *Zeugodacus cucurbitae* (Coq.) (Tephritidae: Diptera), need based application of *Bacillus thuringiensis* 2 g L^{-1} as blanket spray for all the treatments if incidence of cucumber moth, *Diaphania indica* (Saunders) (Crambidae: Lepidoptera) was observed.

Data Recording

The data were recorded from five randomly selected plants from each spot for the respective module. Whiteflies and jassids were counted from three leaves (top, middle, and bottom region) sampled from each of 5 random plants. The observations were recorded at weekly interval in each plot of different modules including untreated control. Number of bitter gourd yellow mosaic virus (BGYMV) infected plants at the end of the crop season from each plot were counted and calculated by the following formula:

$$\text{BGYMV incidence (\%)} = \frac{\text{number of BGYMV infected bitter gourd plants}}{\text{total number of bitter gourd plants in that plot}} \text{ X } 100$$

Two prominent polyphagous predators *viz*., spiders and lady bird beetles (*Coccinella septempunctata* Linn., *Cheilomenes sexmaculata* (Fab.), *Brumoides suturalis* (Fab.), *Micraspis discolour*) (Coleoptera: Coccinellidae) were recorded during the observation. Numbers of these predators per plant were noted and twenty plants from each pest management modules were taken. As regards the yield, different pickings made separately from entire plot from each module were added and converted to hectare basis.

Statistical Analysis

The data were subjected to Analysis of Variance (ANOVA) with least significant difference (p = 0.05) as test criterion using SAS software (version 9.3). The yield data were converted to hectare basis and the economics calculated. Incremental cost-benefit analysis was expressed in terms of ratio using the following formula (Satpathy et al. 2016):

$$\text{Incremental cost benefit ratio (ICBR)} = \frac{\text{net return (₹ ha-1)}}{\text{cost of treatment (₹ h}^{\text{a-1)}}}$$

RESULTS AND DISCUSSION

Effect of Pest Management Modules on Sucking Insect Pests

Effects of different pest management modules on whiteflies and jassids infesting bitter gourd were evaluated for three consecutive years (Table 1). Out of the three tested pest management modules, lowest whiteflies population (0.63 per leaf) was recorded in IPM module (treatment 3) and thereby registered maximum per cent reduction over control (PROC) of 70.14 followed by bio-intensive pest management module (treatment 1) (0.90 per leaf) with 57.35 PROC. Nevertheless, this trend was unlike in case of leaf hopper incidence. The chemical pest management module (treatment 2) harboured minimum leaf hopper population (0.62) with maximum PROC (62.19) compared to other pest management modules under Varanasi conditions (Table 1).

Effects on Natural Enemies

Effect of these pest management modules on two most abundant predators *viz*., lady bird beetles (*C. septempunctata*, *C. sexmaculata*, *B. suturalis*, *M. discolour*) and spiders in bitter gourd ecosystems were recorded. Amongst the field evaluated modules, biointensive pest management (treatment 1) harboured maximum numbers of spiders (1.20 per plant) and lady bird beetles (1.85 per plant) followed by IPM module (treatment 3) (1.07 and 1.68 per plant, respectively). Interestingly, the chemical pest management module (treatment 2) had the lowest numbers of lady bird beetle (0.82 per plant) and spider (0.97 per plant) populations during the observation (Figure 1). In contrast, the untreated control bitter gourd plots had the significantly highest numbers of these polyphagous predators.

Incidence of Bitter Gourd Yellow Mosaic Virus

Bitter gourd yellow mosaic virus (BGYMV) is a serious sporadic disease in the region transmitted by whitefly, *B. tabaci*. Many farmers of the region had suffered severe crop losses due to this viral disease many times as they often followed the advised from the local pesticides retailers for its management. Incidences of BGYMV were lower in all the three tested pest management modules than the untreated control plots which registered 13.58% incidence during the observation (Figure 2). However, amongst the three tested modules, there were

Table 1. Effect of different pest management modules on bitter gourd sucking pests during 2019–2021 in Varanasi, Uttar Pradesh, India

Module	Whitefly per leaf					Jassids per leaf				
	2019	2020	2021	Average	PROC[#]	2019	2020	2021	Average	PROC
T1- BIPM	0.93	0.79	0.98	0.90	57.35	0.74	0.66	0.83	0.74	54.88
T2- CPM	0.89	0.83	1.19	0.97	54.03	0.67	0.48	0.71	0.62	62.19
T3- IPM	0.54	0.51	0.83	0.63	70.14	0.39	0.71	0.92	0.67	59.15
T4- UC	2.12	1.93	2.27	2.11	--	1.69	1.45	1.77	1.64	--
SEm (±)	0.14	0.23	0.19	0.21	--	0.11	0.09	0.14	0.13	--
LSD (5%)	0.33	0.48	0.39	0.43	--	0.27	0.21	0.32	0.28	--

PROC = per cent reduction over control

BIPM = bio-intensive pest management, CPM = chemical pest management, IPM = integrated pest management, UC = untreated control.

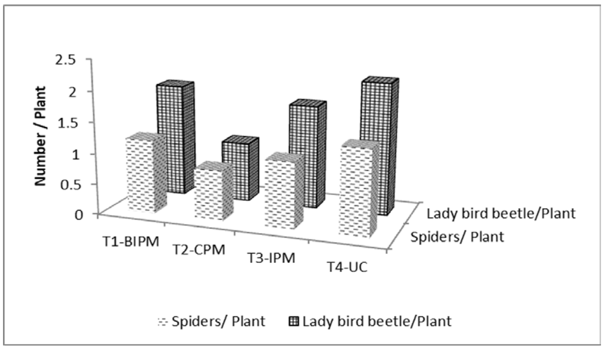

Figure 1. Abundance of spiders and lady bird beetles (per plant) in different pest management modules in bitter gourd in Varanasi, Uttar Pradesh, India

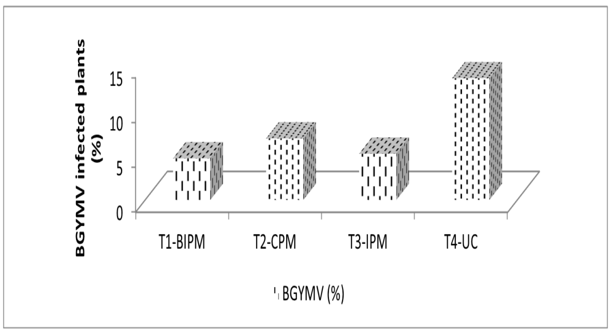

Figure 2. Incidence of bitter gourd yellow mosaic virus (BGYMV) on different pest management modules in Varanasi, Uttar Pradesh, India

no significant differences among them in virus incidence. Recently, Nagendran et al. (2021) reported that integrated disease management module with mulching had registered lowest chilli leaf curl disease incidence (10%) accompanied with maximum fruit yield (34.92 q acre^{-1}) in chilli compared to farmers' practices and untreated control under Varanasi conditions.

Economics of the Different Pest Management Modules

Economics in terms of incremental cost benefit ratio (ICBR) of different pest management modules were also computed. It is evident that highest healthy fruit yields (171, 179, and 153 q ha^{-1}) were recorded from the IPM module for three consecutive years (2019, 2020, and 2021, respectively), followed by chemical pest management module (153, 162, and 141 q ha^{-1} for the year 2019, 2020, and 2021, respectively). The IPM module had recorded 42.48 per cent higher healthy fruit yield than the untreated control whereas the corresponding values were 29.14 and 23.45 per cent for chemical and biointensive pest management modules (Table 2). In terms of net profit, maximum net profit of ₹71.211 was obtained from IPM module 3 with highest incremental cost benefit ratio of 1:5.18 followed by biointensive pest management module (1:4.99). Lower cost of IPM inputs like azadirachtin, neem oil, entomopathogenic fungi *viz*., *B. bassiana*, *L. lecanii* compared to newer chemical insecticides could be the reason for higher ICBR of biointensive pest management module than the corresponding chemical module.

Integrated pest management module comprised a series pest management options in its package from crop raising onwards to till maturity of fruits. Seed treatment with systemic insecticide was aimed to confer initial plant protection measures to sucking pests. Furthermore, installation of yellow sticky traps for sucking pests could prove effective as a mechanical control measure by trapping a large number of whiteflies and leaf hoppers. Spraying of plant origin insecticide like azadirachtin, neem oil, entomopathogenic fungi (*B. bassiana* and *L. lecanii*) and newer molecule insecticides with diverse mode of action was found highly effective against the polyphagous pest like *B. tabaci* (Parmar and Singh 1993; IRAC 2017; Keerio et al. 2020). However, chemical pest management module comprising neonicotinoids like imidacloprid and thiamethoxam and diamide insecticide like cyantraniliprole was found most effective against leaf hopper infesting bitter gourd. In enigma, the another nefarious sucking pest *viz*., whiteflies in bitter gourd might have been developed resistance against these neonicotinoid insecticides which are being used over a decade in the region for the management of sucking pests. In our earlier work, we reported that cabbage aphid, *Myzus persicae* (Sulzer) had developed 5.90 and 2.51 fold resistance against imidacloprid 17.8 SL and thiamethoxam 25 WG during 2010 to 2018 under Varanasi condition (Halder et al. 2018). Being polyphagous in nature and having more than four hundred host plants whitefly, *B. tabaci* might have developed higher level of resistance as compared to leaf hoppers having limited number of host plants.

Since the untreated control plots were devoid of any chemical sprayings were actually the "predators' heaven" or "predators' bank" and harboured maximum numbers of predatory coccinellid beetles and polyphagous spiders. All the four lady bird beetles *viz*., *C. septempunctata*, *C. sexmaculata*, *B. suturalis*, and *M. discolour* (Coccinellidae: Coleoptera) were recorded during the observation. Similarly, spiders mainly lynx and jumping spiders were dominant in the list. In paradox, chemical pest management module where only chemical insecticides were sprayed might be responsible for low population of these beneficial predators. Bio-intensive pest management module where biopesticides like azadirachtin and entomopathogenic fungi were sprayed was found to be safe to these polyphagous predators and could be an ecofriendly pest management option.

In a similar vein, Kumari *et al*. (2021) documented that integrated module (seed treatment with thiamethoxam 70 WS, removal of damaged cotyledonary leaves, spraying

Table 2. Economics of IPM and non-IPM adopted fields in bitter gourd in Varanasi, Uttar Pradesh, India

Treatment	Yield of healthy fruits (q ha^{-1})	Increase in yield over control (q ha^{-1})	Increase in yield per cent over control	Cost of increase yield (₹ha^{-1})	Cost of plant protection treatments (₹ha^{-1})	Net profit (₹ha^{-1})	Incremental cost benefit ratio
T1- BIPM	145.3	27.6	23.45	46900	7828	39072	1:4.99
T2- CPM	152.0	34.3	29.14	58280	11233	47047	1:4.18
T3- IPM	167.7	50	42.48	84960	13749	71211	1:5.18
T4- UC	117.7	--	--	--	--	--	--

Cost of bitter gourd was ₹20 kg^{-1}; Labourer charge was ₹280 per day; Spray volume was 500 L of water.

BIPM = bio-intensive pest management, CPM = chemical pest management, IPM = integrated pest management, UC = untreated control.

of emamectin benzoate, spraying of neem oil, installation of cuelure traps, spraying of spinosad) had recorded highest bitter gourd fruit yield (16 t ha^{-1}) and highest benefit cost ratio (2.61:1) along with lowest fruit fly damage in Hyderabad, India. In another study, in okra the IPM module comprising sprayings of chlorantraniliprole, NSKE, emamectin benzoate, *Bacillus thuringiensis* and nimbecidine their need based rotation was most effective in reducing the fruit borer damage (71.74%) and yellow vein mosaic disease (17.75%) with significant increase in the yield (177.7 q ha^{-1}) over control (Kodandaram et al. 2017). Recently, Birah et al. (2012) documented that integrated module including seed treatment with imidacloprid + sowing of maize at the borders as barrier crop + weekly clipping of infested shoots and fruits + erection of pheromone trap + foliar spray of NSKE, spinosad and karanj oil at 45, 60 and 75 DAS, respectively registered significantly lower jassids population (3.32 jassids per leaf) than farmers' practices (5.31 jassids per leaf) and untreated control (10.12 jassids per leaf).

CONCLUSION

Three different pest management modules were synthesized and evaluated against the major sucking insect pests of bitter gourd. The integrated pest management module comprised seed treatment with imidacloprid 48 FS and installation of yellow sticky traps, border crop with maize, spraying of azadirachtin 1500 ppm, thiamethoxam 25 WG, imidacloprid 70 WG, cyantraniliprole 10.26 OD, neem oil (0.5%) + *Lecanicillium lecanii* and neem oil (0.5%) + *Beauveria bassiana* from 20 DAS onwards to till 70 DAS at 10 days intervals each harboured lowest whiteflies population with maximum PROC. Furthermore, the highest healthy fruit yields were recorded from the integrated pest management module accompanied with higher predatory lady bird beetles and polyphagous spider populations. In terms of return, maximum net profit was obtained from this module with highest benefit cost ratio.

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