



Management of American serpentine leaf miner, *Liriomyza trifolii* (Burgess) in tomato under protected cultivation

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Abstract: The serpentine leaf miner, *Liriomyza trifolii*, is one of the most destructive invasive pests introduced to India from the American subcontinent during the nineteenth century. For ecofriendly management of *L. trifolii* the experiment was conducted at horticulture farm, College of Horticulture, S. D. Agricultural University, Jagudan (Mehsana), Gujarat in the *rabi* season of 2020-21 and 2021-22. Nine botanical insecticides were tested and among that neem seed kernel extract at 5% was significantly superior and recorded the lowest damage (9.80%) which was statistically at par with tobacco decoction at 2% (10.52%) and azadirachtin at 1500 ppm (11.13%). Similarly, based on the number of mines per three compound leaves, neem seed kernel extract at 5% demonstrated superior efficacy by recording the lowest number of mines (10.59 mines/3 compound leaves). The application of neem seed kernel extract at 5% resulted in the highest tomato fruit yield, harvesting 449.16 q/ha, a result on par with azadirachtin at 1500 ppm (445.83 q/ha) and tobacco decoction at 2% (436.00 q/ha). The incorporation of biopesticides into the management strategy presents a promising avenue for sustainable and environmentally friendly tomato production in protected cultivation systems.

Keywords: *Liriomyza trifolii*, tomato, NSKE, azadirachtin, tobacco decoction

INTRODUCTION

Tomato (*Solanum lycopersicum*) is a major and widely cultivated vegetable crop in India, making substantial contributions to the agricultural sector. Cultivated extensively across diverse agro-climatic regions, tomatoes are a staple ingredient in Indian cuisine, fulfilling significant nutritional needs. In India, tomato cultivation spans over an area of 8,43,000 hectares, yielding a production of 2,06,94,000 metric tons with a productivity rate of 24.55 metric tons per hectare during the 2022-23 period (Anonymous, 2023a). Specifically in Gujarat, it is cultivated across 67,874 hectares, producing 19,22,220 metric tons with a productivity rate of 28.32 metric tons per hectare during the same period (Anonymous, 2023b). Tomato cultivation faces challenges from various insect pests, including the fruit borer, *Helicoverpa armigera*, *Bemisia tabaci*, *Aphis gossypii*, the leaf-eating caterpillar *Spodoptera litura*, *Thrips tabaci*, the American serpentine leaf miner, *Liriomyza trifolii*, and the two-spotted spider mite, *Tetranychus urticae* (Misra, 2010; Dodiya *et al.*, 2023). Of particular concern is the invasive pest *Liriomyza trifolii*, which was inadvertently introduced into India from the American subcontinent alongside chrysanthemum cuttings (Parella, 1987). Initially recorded on 55 plant species, its host range expanded to approximately 79 species, including pulses, oilseeds, vegetables, green manures, fodder, and fiber crops (Viraktamath *et al.*, 1993; Srinivasan *et al.*, 1995). Larval feeding by *L. trifolii* diminishes plant marketability due to aesthetic damage and reduces photosynthetic capacity, affecting plant

vigor, growth, and yield (Khateeb *et al.*, 2006). In efforts to mitigate these challenges, researchers have explored the use of bio-insecticides such as ethanolic extracts from neem and petroleum ether extracts from jatropha seeds targeting the egg and larval stages of *T. absoluta* (Kona *et al.*, 2014). *Liriomyza trifolii* infestations are particularly detrimental as they result in extensive mining in the spongy mesophyll of foliage and petioles (Parrella *et al.*, 1985), with peak infestation levels recorded by Satti (1997) at 6.9-8.6 infested leaves per 50 leaves. Recognizing the demand for environmentally friendly and sustainable pest management practices, biopesticides emerge as a targeted and eco-conscious approach to pest control (Dodiya *et al.*, 2023). As the call for pesticide-free and sustainable agricultural methods grows louder, the findings of this research offer significant promise for tomato growers, especially those engaged in protected cultivation. By highlighting the efficacy of biopesticides in managing *trifolii*, this study contributes to ongoing discussions on environmentally conscious pest control strategies, promoting a balanced and resilient agricultural ecosystem.

MATERIALS AND METHODS

To identify effective and cost-efficient botanical insecticides for managing *L. trifolii* infestations in tomatoes under protected cultivation, the study tested the following botanicals: Neem Seed Kernel Extract (NSKE), Jatropha oil, Pongamia oil, Neem oil, Citronella oil, Custard apple leaf extract, Azadirachtin, Garlic bulb extract, and Tobacco decoction. The experiment was

Table 1. Bio-efficacy of botanicals against leaf miner in tomato (2020-21)

Tr. No.	Treatments	Damage leaves (%) at indicated days after spray												Pooled over periods and sprays
		1 st spray			2 nd spray			3 rd spray			Pooled			
		3 DAS	7 DAS	10 DAS	3 DAS	7 DAS	10 DAS	3 DAS	7 DAS	10 DAS				
T ₁	NSKE 5%	5.00 (24.50)	3.79 ^a (13.86)	3.37 ^a (10.86)	3.87 ^a (14.48)	3.28 ^a (10.26)	3.07 ^a (8.92)	3.52 ^a (11.89)	3.22 ^a (9.87)	2.82 ^a (7.45)	2.51 ^a (5.80)	3.29 ^a (10.32)	3.28 ^a (10.26)	
T ₂	Jatropha oil 1%	4.91 (23.61)	4.63 ^c (20.94)	4.52 ^b (19.93)	4.84 ^{cd} (22.93)	4.45 ^b (19.30)	4.25 ^c (17.56)	4.63 ^{bc} (20.94)	4.41 ^c (18.95)	4.06 ^b (15.98)	3.81 ^c (14.02)	4.44 ^b (19.21)	4.41 ^c (18.95)	
T ₃	Pongamia oil 1%	4.87 (23.22)	4.55 ^c (20.20)	4.44 ^b (19.21)	4.76 ^{cd} (22.16)	4.36 ^b (18.51)	4.16 ^c (16.81)	4.55 ^{bc} (20.20)	4.31 ^c (18.08)	3.95 ^b (15.10)	3.69 ^c (13.12)	4.36 ^b (18.51)	4.31 ^c (18.08)	
T ₄	Neem oil 0.5%	4.90 (23.51)	4.59 ^c (20.57)	4.48 ^b (19.57)	4.80 ^{cd} (22.54)	4.40 ^b (18.86)	4.21 ^c (17.22)	4.59 ^{bc} (20.57)	4.36 ^c (18.51)	4.00 ^b (15.50)	3.75 ^c (13.56)	4.40 ^b (18.86)	4.36 ^c (18.51)	
T ₅	Citronella oil 1%	4.86 (23.12)	4.31 ^{abc} (18.08)	4.19 ^b (17.06)	4.53 ^{bc} (20.02)	4.10 ^b (16.31)	3.90 ^{bc} (14.71)	4.30 ^{ab} (17.99)	4.06 ^{bc} (15.98)	3.68 ^b (13.04)	3.40 ^{bc} (11.06)	4.10 ^b (16.31)	4.06 ^b (15.98)	
T ₆	Custard apple leaf extract 10%	4.88 (23.31)	4.56 ^c (20.29)	4.45 ^b (19.30)	4.77 ^{cd} (22.25)	4.37 ^b (18.60)	4.17 ^c (16.89)	4.56 ^{bc} (20.29)	4.33 ^c (18.25)	3.97 ^b (15.26)	3.71 ^c (13.26)	4.36 ^b (18.51)	4.33 ^c (18.25)	
T ₇	Azadirachtin 1500 ppm	4.50 (19.75)	3.95 ^{ab} (15.10)	3.54 ^a (12.03)	4.08 ^{ab} (16.15)	3.45 ^a (11.40)	3.24 ^{ab} (10.00)	3.62 ^a (12.60)	3.43 ^{ab} (11.26)	3.04 ^a (8.74)	2.81 ^{ab} (7.40)	3.44 ^a (11.33)	3.47 ^a (11.54)	
T ₈	Garlic bulb extract 5%	4.77 (22.25)	4.53 ^b (20.02)	4.41 ^b (18.95)	4.84 ^{cd} (22.93)	4.44 ^b (19.21)	4.22 ^c (17.31)	4.63 ^{bc} (20.94)	4.41 ^c (18.95)	4.05 ^b (15.90)	3.80 ^c (13.94)	4.43 ^b (19.12)	4.37 ^c (18.60)	
T ₉	Tobacco decoction 2%	4.54 (20.11)	3.81 ^a (14.02)	3.38 ^a (10.92)	3.94 ^{ab} (15.02)	3.33 ^a (10.59)	3.17 ^{ab} (9.55)	3.59 ^a (12.39)	3.41 ^{ab} (11.13)	2.99 ^a (8.44)	2.80 ^{ab} (7.34)	3.36 ^a (10.79)	3.39 ^a (10.99)	
T ₁₀	Untreated control	4.89 (23.41)	5.26 ^d (27.17)	5.36 ^d (28.23)	5.38 ^d (28.44)	5.40 ^d (28.66)	5.40 ^d (28.66)	5.39 ^d (28.55)	5.40 ^d (28.66)	5.42 ^d (28.88)	5.41 ^d (28.77)	5.40 ^d (28.66)	5.39 ^d (28.55)	
S. Em. ±		0.24	0.18	0.20	0.19	0.20	0.23	0.25	0.21	0.20	0.19	0.13	0.12	
P		-	-	-	-	-	-	-	-	-	-	0.07	0.06	
S		-	-	-	-	-	-	-	-	-	-	-	0.037	
T x P		-	-	-	-	-	-	-	-	-	-	0.23	0.20	
T x S		-	-	-	-	-	-	-	-	-	-	-	0.119	
P x S		-	-	-	-	-	-	-	-	-	-	-	0.065	
T x P x S		-	-	-	-	-	-	-	-	-	-	-	0.206	
C.D. at 5%	NS	0.54	0.59	0.59	0.56	0.59	0.67	0.72	0.63	0.59	0.56	0.31	0.28	
C.V. (%)	8.48	7.17	8.19	7.21	8.40	9.90	9.90	9.75	8.89	9.10	9.27	9.38	8.65	

Note: 1. Figures outside the parentheses are $\sqrt{X + 0.5}$ transformed values and those inside the parentheses are retransformed values
 2. Treatment means followed by the same letter are not significantly different by Duncan's New Multiple Range Test (DNMRT) at 5% level of significance

Table 2. Bio-efficacy of botanicals against leaf miner in tomato (2021-22)

Tr. No.	Treatments	Before spray	Damage leaves (%) at indicated days after spray										Pooled over periods and sprays		
			1 st spray			2 nd spray				3 rd spray					
			3 DAS	7 DAS	10 DAS	Pooled	3 DAS	7 DAS	10 DAS	Pooled	3 DAS	7 DAS	10 DAS	Pooled	
T ₁	NSKE 5%	4.9 (23.51)	3.60 ^a (12.46)	3.34 ^a (10.66)	3.65 ^a (12.82)	3.53 ^a (11.96)	3.12 ^a (9.23)	2.91 ^a (7.97)	3.32 ^a (10.52)	3.12 ^a (9.23)	3.18 ^a (9.61)	2.71 ^a (6.84)	2.46 ^a (5.55)	2.78 ^a (7.23)	3.14 (9.36)
T ₂	Jatropha oil 1%	4.82 (22.73)	4.53 ^{cd} (20.02)	4.49 ^b (19.66)	4.71 ^{cd} (21.68)	4.58 ^b (20.48)	4.34 ^c (18.34)	4.13 ^b (16.56)	4.49 ^c (19.66)	4.32 ^b (18.16)	4.30 ^c (17.99)	4.02 ^b (15.66)	3.77 ^b (13.71)	4.03 ^c (15.74)	4.31 ^d (18.08)
T ₃	Pongamia oil 1%	4.77 (22.25)	4.44 ^c (19.21)	4.40 ^b (18.86)	4.62 ^{cd} (20.84)	4.49 ^b (19.66)	4.25 ^c (17.56)	4.04 ^b (15.82)	4.40 ^c (18.86)	4.23 ^b (17.39)	4.19 ^c (17.06)	3.91 ^b (14.79)	3.65 ^b (12.82)	3.91 ^{bc} (14.79)	4.21 ^d (17.22)
T ₄	Neem oil 0.5%	4.84 (22.93)	4.48 ^{cd} (19.57)	4.45 ^b (19.3)	4.66 ^{cd} (21.22)	4.53 ^b (20.02)	4.29 ^c (17.9)	4.09 ^b (16.23)	4.44 ^c (19.21)	4.28 ^b (17.82)	4.25 ^c (17.56)	3.96 ^b (15.18)	3.71 ^b (13.26)	3.97 ^{bc} (15.26)	4.26 ^d (17.65)
T ₅	Citronella oil 1%	4.76 (22.16)	4.19 ^{abc} (17.06)	4.15 ^b (16.72)	4.38 ^{bc} (18.68)	4.24 ^b (17.48)	3.99 ^{bc} (15.42)	3.77 ^b (13.71)	4.15 ^{bc} (16.72)	3.97 ^b (15.26)	3.94 ^{bc} (15.02)	3.63 ^b (12.68)	3.36 ^b (10.79)	3.64 ^b (12.75)	3.95 ^c (15.10)
T ₆	Custard apple leaf extract 10%	4.78 (22.35)	4.46 ^c (19.39)	4.42 ^b (19.04)	4.63 ^{cd} (20.94)	4.50 ^b (19.75)	4.26 ^c (17.65)	4.06 ^b (15.98)	4.41 ^c (18.95)	4.24 ^b (17.48)	4.22 ^c (17.31)	3.93 ^b (14.94)	3.67 ^b (12.97)	3.94 ^{bc} (15.02)	4.23 ^d (17.39)
T ₇	Azadirachtin 1500 ppm	4.45 (19.30)	3.78 ^{ab} (13.79)	3.51 ^a (11.82)	3.87 ^{ab} (14.48)	3.72 ^a (13.34)	3.39 ^{ab} (10.99)	3.08 ^a (8.99)	3.46 ^{ab} (11.47)	3.31 ^a (10.46)	3.29 ^{ab} (10.32)	2.95 ^a (8.20)	2.77 ^a (7.17)	3.00 ^a (8.50)	3.35 ^b (10.72)
T ₈	Garlic bulb extract 5%	4.72 (21.78)	4.42 ^{bc} (19.04)	4.38 ^b (18.68)	4.70 ^{cd} (21.59)	4.50 ^b (19.75)	4.34 ^c (18.34)	4.11 ^b (16.39)	4.48 ^c (19.57)	4.31 ^b (18.08)	4.30 ^c (17.99)	4.02 ^b (15.66)	3.76 ^b (13.64)	4.02 ^c (15.66)	4.28 ^d (17.82)
T ₉	Tobacco decoction 2%	4.47 (19.48)	3.68 ^a (13.04)	3.38 ^a (10.92)	3.75 ^{ab} (13.56)	3.60 ^a (12.46)	3.18 ^a (9.61)	3.04 ^a (8.74)	3.41 ^a (11.13)	3.21 ^a (9.80)	3.26 ^{ab} (10.13)	2.87 ^a (7.74)	2.75 ^a (7.06)	2.97 ^a (8.32)	3.26 ^{ab} (10.13)
T ₁₀	Untreated control	4.83 (22.83)	5.16 ^d (26.13)	5.20 ^c (26.54)	5.26 ^d (27.17)	5.21 ^c (26.64)	5.29 ^d (27.48)	5.31 ^d (27.70)	5.28 ^d (27.38)	5.29 ^c (27.48)	5.31 ^d (27.70)	5.33 ^c (27.91)	5.38 ^c (28.44)	5.34 ^d (28.02)	5.28 ^c (27.38)
S. Em. ±	T	0.23	0.20	0.18	0.20	0.11	0.22	0.22	0.23	0.13	0.22	0.18	0.17	0.11	0.067
	P	-	-	-	-	0.06	-	-	-	0.07	-	-	-	0.06	0.037
	S	-	-	-	-	-	-	-	-	-	-	-	-	-	0.037
	T x P	-	-	-	-	0.19	-	-	-	0.23	-	-	-	0.19	0.117
	T x S	-	-	-	-	-	-	-	-	-	-	-	-	-	0.117
	P x S	-	-	-	-	-	-	-	-	-	-	-	-	-	0.064
	T x P x S	-	-	-	-	-	-	-	-	-	-	-	-	-	0.203
C.D. at 5%	T	NS	0.59	0.52	0.59	0.26	0.66	0.65	0.68	0.31	0.64	0.53	0.50	0.26	0.188
C.V. (%)		8.29	8.04	7.35	7.84	7.76	9.60	9.85	9.59	9.68	9.30	8.39	8.35	8.74	8.73

Note: 1. Figures outside the parentheses are $\sqrt{X + 0.5}$ transformed values and those inside the parentheses are retransformed values
 2. Treatment means followed by the same letter are not significantly different by Duncan's New Multiple Range Test (DNMRT) at 5% level of significance

Table 3. Bio-efficacy of botanicals against leaf miner in tomato (2020-21)

Tr. No.	Treatments	Before spray	No. of mines/ 3 compound leaves at indicated days after spray										Pooled over periods and sprays		
			1 st spray			2 nd spray			3 rd spray						
			3 DAS	7 DAS	10 DAS	Pooled	3 DAS	7 DAS	10 DAS	Pooled	3 DAS	7 DAS	10 DAS	Pooled	
T ₁	NSKE 5%	4.28 (17.82)	3.56 ^a (12.17)	3.37 ^a (10.86)	3.64 ^a (12.75)	3.52 ^a (11.89)	3.54 ^a (12.03)	3.39 ^a (10.99)	3.56 ^a (12.17)	3.50 ^a (11.75)	3.41 ^a (11.13)	3.22 ^a (9.87)	2.89 ^a (7.85)	3.17 ^a (9.55)	3.40 ^a (11.06)
T ₂	Jatropha oil 1%	4.13 (16.56)	4.13 ^{bc} (16.56)	4.05 ^{bcd} (15.90)	4.25 ^{bcd} (17.56)	4.14 ^b (16.64)	4.22 ^{cd} (17.31)	4.13 ^c (16.56)	4.23 ^{cde} (17.39)	4.19 ^b (17.06)	4.10 ^{bcd} (16.31)	3.97 ^c (15.26)	3.71 ^b (13.26)	3.92 ^b (14.87)	4.09 ^b (16.23)
T ₃	Pongamia oil 1%	4.39 (18.77)	4.20 ^{cd} (17.14)	4.13 ^{de} (16.56)	4.32 ^{cd} (18.16)	4.22 ^b (17.31)	4.29 ^{cd} (17.90)	4.21 ^{cd} (17.22)	4.31 ^{de} (18.08)	4.27 ^b (17.73)	4.18 ^{ef} (16.97)	4.11 ^c (16.39)	3.86 ^b (14.40)	4.05 ^b (15.90)	4.18 ^b (16.97)
T ₄	Neem oil 0.5%	4.09 (16.23)	4.12 ^{bc} (16.47)	4.04 ^{bcd} (15.82)	4.24 ^{bcd} (17.48)	4.13 ^b (16.56)	4.22 ^{cd} (17.31)	4.13 ^c (16.56)	4.23 ^{cde} (17.39)	4.19 ^b (17.06)	4.10 ^{bcd} (16.31)	4.04 ^c (15.82)	3.79 ^b (13.86)	3.97 ^b (15.26)	4.10 ^b (16.31)
T ₅	Citronella oil 1%	4.25 (17.56)	4.06 ^{abc} (15.98)	3.98 ^{abcd} (15.34)	4.18 ^{abc} (16.97)	4.0 ^b (16.06)	4.15 ^{bc} (16.72)	4.06 ^{bc} (15.98)	4.17 ^{bcd} (16.89)	4.13 ^b (16.56)	4.04 ^{abcde} (15.82)	3.87 ^{bc} (14.48)	3.61 ^b (12.53)	3.84 ^b (14.25)	4.01 ^b (15.58)
T ₆	Custard apple leaf extract 10%	4.39 (18.77)	4.16 ^{cd} (16.81)	4.07 ^{bcd} (16.06)	4.28 ^{cd} (17.82)	4.17 ^b (16.89)	4.24 ^{cd} (17.48)	4.15 ^c (16.72)	4.26 ^{de} (17.65)	4.22 ^b (17.31)	4.13 ^{def} (16.56)	3.96 ^c (15.18)	3.70 ^b (13.19)	3.93 ^b (14.94)	4.11 ^b (16.39)
T ₇	Azadirachtin 1500 ppm	3.97 (15.26)	3.57 ^{ab} (12.24)	3.43 ^{abc} (11.26)	3.67 ^{ab} (12.97)	3.56 ^a (12.17)	3.58 ^{ab} (12.32)	3.43 ^{ab} (11.26)	3.62 ^{abc} (12.60)	3.54 ^a (12.03)	3.47 ^{abcde} (11.54)	3.28 ^{ab} (10.26)	2.97 ^a (8.32)	3.24 ^a (10.00)	3.45 ^a (11.40)
T ₈	Garlic bulb extract 5%	4.40 (18.86)	4.17 ^{cd} (16.89)	4.10 ^{cde} (16.31)	4.29 ^{cd} (17.90)	4.19 ^b (17.06)	4.23 ^{cd} (17.39)	4.15 ^c (16.72)	4.25 ^{cde} (17.56)	4.21 ^b (17.22)	4.12 ^{def} (16.47)	3.96 ^c (15.18)	3.70 ^b (13.19)	3.92 ^b (14.87)	4.11 ^b (16.39)
T ₉	Tobacco decoction 2%	4.17 (16.89)	3.57 ^{ab} (12.24)	3.42 ^{ab} (11.20)	3.64 ^a (12.75)	3.54 ^a (12.03)	3.56 ^{ab} (12.17)	3.40 ^a (11.06)	3.60 ^{ab} (12.46)	3.52 ^a (11.89)	3.45 ^{abcd} (11.40)	3.26 ^a (10.13)	2.96 ^a (8.26)	3.22 ^a (9.87)	3.43 ^a (11.26)
T ₁₀	Untreated control	4.35 (18.42)	4.72 ^d (21.78)	4.74 ^c (21.97)	4.82 ^d (22.73)	4.76 ^c (22.16)	4.83 ^d (22.83)	4.84 ^d (22.93)	4.85 ^c (23.02)	4.84 ^c (22.93)	4.81 ^f (22.64)	4.80 ^d (22.54)	4.82 ^c (22.73)	4.81 ^c (22.64)	4.81 ^c (22.54)
S. Em. ±	T	0.22	0.17	0.20	0.18	0.11	0.19	0.20	0.19	0.11	0.21	0.19	0.16	0.11	0.063
	P	-	-	-	-	0.06	-	-	-	0.06	-	-	-	0.06	0.034
	S	-	-	-	-	-	-	-	-	-	-	-	-	-	0.034
	T x P	-	-	-	-	0.18	-	-	-	0.20	-	-	-	0.19	0.109
	T x S	-	-	-	-	-	-	-	-	-	-	-	-	-	0.109
	P x S	-	-	-	-	-	-	-	-	-	-	-	-	-	0.059
	T x P x S	-	-	-	-	-	-	-	-	-	-	-	-	-	0.189
C.D. at 5%	T	NS	0.50	0.59	0.53	0.25	0.58	0.60	0.57	0.27	0.61	0.56	0.48	0.26	0.147
C.V. (%)		8.98	7.33	8.79	7.46	7.87	8.26	8.76	8.14	8.39	8.95	8.56	7.85	8.51	8.25

Note: 1. Figures outside the parentheses are $\sqrt{\square + 0.5}$ transformed values and those inside the parentheses are retransformed values
 2. Treatment means followed by the same letter are not significantly different by Duncan's New Multiple Range Test (DNMRT) at 5% level of significance

Table 4. Bio-efficacy of botanicals against leaf miner in tomato (2021-22)

Tr. No.	Treatments	No. of mines/3 compound leaves at indicated days after spray															Pooled over periods and sprays
		1 st spray					2 nd spray					3 rd spray					
		Before spray	3 DAS	7 DAS	10 DAS	Pooled	3 DAS	7 DAS	10 DAS	Pooled	3 DAS	7 DAS	10 DAS	Pooled			
T ₁	NSKE 5%	4.25 (17.56)	3.50 ^{ab} (11.75)	3.29 ^a (10.32)	3.55 ^a (12.10)	3.45 ^a (11.40)	3.33 ^a (10.59)	3.19 ^a (9.68)	3.38 ^a (10.92)	3.30 ^a (10.39)	3.23 ^a (9.93)	3.06 ^a (8.86)	2.78 ^a (7.23)	3.02 ^a (8.62)	3.23 ^a (9.93)		
T ₂	Jatropha oil 1%	4.09 (16.23)	4.07 ^{bc} (16.06)	3.97 ^{abc} (15.26)	4.18 ^{bed} (16.97)	4.07 ^b (16.06)	4.03 ^b (15.74)	3.93 ^b (14.94)	4.09 ^c (16.23)	4.01 ^b (15.58)	3.93 ^c (14.94)	3.84 ^c (12.53)	3.61 ^b (13.86)	3.79 ^b (13.86)	3.93 ^c (14.94)		
T ₃	Pongamia oil 1%	4.36 (18.51)	4.16 ^{bc} (16.81)	4.05 ^{cd} (15.90)	4.24 ^{cd} (17.48)	4.15 ^b (16.72)	4.12 ^b (16.47)	4.01 ^b (15.58)	4.16 ^c (16.81)	4.10 ^b (16.31)	4.03 ^c (15.74)	3.99 ^c (15.42)	3.78 ^b (13.79)	3.94 ^b (15.02)	4.03 ^c (15.74)		
T ₄	Neem oil 0.5%	4.06 (15.98)	4.11 ^{bc} (16.39)	3.96 ^{abc} (15.18)	4.17 ^{bed} (16.89)	4.08 ^b (16.15)	4.03 ^b (15.74)	3.93 ^b (14.94)	4.09 ^c (16.23)	4.02 ^b (15.66)	3.94 ^c (15.02)	3.91 ^c (14.79)	3.70 ^b (13.19)	3.85 ^b (14.32)	3.94 ^c (15.02)		
T ₅	Citronella oil 1%	4.22 (17.31)	3.40 ^a (11.06)	3.90 ^{abc} (14.71)	4.10 ^{abc} (16.31)	3.99 ^b (15.42)	3.96 ^{ab} (15.18)	3.86 ^b (14.40)	4.03 ^{bc} (15.74)	3.95 ^b (15.10)	3.88 ^{bc} (14.55)	3.73 ^{bc} (13.41)	3.52 ^b (11.89)	3.71 ^b (13.26)	3.88 ^{bc} (14.55)		
T ₆	Custard apple leaf extract 10%	4.35 (18.42)	4.11 ^{bc} (16.39)	3.99 ^{bc} (15.42)	4.21 ^{bed} (17.22)	4.10 ^b (16.31)	4.08 ^b (16.15)	3.95 ^b (15.10)	4.12 ^c (16.47)	4.05 ^b (15.90)	3.97 ^c (15.26)	3.84 ^c (14.25)	3.62 ^b (12.60)	3.81 ^b (14.02)	3.97 ^c (15.26)		
T ₇	Azadirachtin 1500 ppm	3.94 (15.02)	3.56 ^{ab} (12.17)	3.34 ^{abc} (10.66)	3.58 ^{ab} (12.32)	3.49 ^a (11.68)	3.35 ^a (10.72)	3.19 ^a (9.68)	3.50 ^{ab} (11.75)	3.35 ^a (10.72)	3.29 ^{ab} (10.32)	3.13 ^{ab} (9.30)	2.87 ^a (7.74)	3.09 ^a (9.05)	3.29 ^{ab} (10.32)		
T ₈	Garlic bulb extract 5%	4.37 (18.60)	4.12 ^{bc} (16.47)	4.02 ^{bed} (15.66)	4.21 ^{bed} (17.22)	4.12 ^b (16.47)	4.07 ^b (16.06)	3.94 ^b (15.02)	4.11 ^c (16.39)	4.04 ^b (15.82)	3.96 ^c (15.18)	3.83 ^c (14.17)	3.61 ^b (12.53)	3.80 ^b (13.94)	3.96 ^c (15.18)		
T ₉	Tobacco decoction 2%	4.14 (16.64)	3.51 ^{ab} (11.82)	3.32 ^{ab} (10.52)	3.54 ^a (12.03)	3.46 ^a (11.47)	3.35 ^a (10.72)	3.20 ^a (9.74)	3.46 ^a (11.47)	3.34 ^a (10.66)	3.26 ^a (10.13)	3.11 ^{ab} (9.17)	2.84 ^a (7.57)	3.07 ^a (8.92)	3.26 ^a (10.13)		
T ₁₀	Untreated control	4.35 (18.42)	4.65 ^c (21.12)	4.71 ^d (21.68)	4.80 ^d (22.54)	4.72 ^c (21.78)	4.85 ^c (23.02)	4.86 ^c (23.12)	4.91 ^d (23.61)	4.88 ^c (23.31)	4.94 ^d (23.90)	4.96 ^d (24.10)	4.97 ^c (24.20)	4.96 ^c (24.10)	4.94 ^d (23.90)		
S. Em. ±	T	0.17	0.20	0.21	0.19	0.12	0.20	0.18	0.17	0.11	0.19	0.21	0.16	0.11	0.0633		
	P	-	-	-	-	0.06	-	-	-	0.06	-	-	-	0.06	0.0347		
	S	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0347		
	T x P	-	-	-	-	0.20	-	-	-	0.19	-	-	-	0.19	0.1098		
	T x S	-	-	-	-	-	-	-	-	-	-	-	-	-	0.1098		
	P x S	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0601		
	T x P x S	-	-	-	-	-	-	-	-	-	-	-	-	-	0.1901		
C.D. at 5%	T	NS	0.58	0.61	0.57	0.27	0.60	0.53	0.51	0.25	0.55	0.63	0.46	0.25	0.176		
C.V. (%)		7.06	8.51	9.28	8.25	8.67	8.96	8.16	7.50	8.22	8.39	9.88	7.66	8.73	8.54		

Note: 1. Figures outside the parentheses are $\sqrt{\square + 0.5}$ transformed values and those inside the parentheses are retransformed values
 2. Treatment means followed by the same letter are not significantly different by Duncan's New Multiple Range Test (DNMRT) at 5% level of significance

conducted during the rabi seasons of 2020 and 2021 at the horticulture farm of the College of Horticulture, S. D. Agricultural University, Jagudan (Mehsana), Gujarat, utilizing a completely randomized design with three replications and ten treatments. Tomato plants (Pant polyhouse hybrid tomato 2) were planted with a plot size of 128 m² at 60 cm × 45 cm spacing. All botanicals were prepared following standard protocols. Three applications of botanical insecticides were administered at 10-day intervals, with the first spray applied at the initiation of the pest population. Observations were recorded before spraying and 3, 7, and 10 days after each application. Marketable fruit yield was assessed for all treatments at each harvest. To evaluate the economic viability of the various treatments compared to tomatoes infested by *L. trifolii*, the Incremental Cost Benefit Ratio (ICBR) was calculated.

RESULTS AND DISCUSSION

Based on damage leaves (%)

The results from the *rabi* season of 2020-21 are summarized in Table 1, indicating significant differences among various biopesticide treatments. Plants treated with neem seed kernel extract at 5% exhibited the lowest damage percentage (10.26%) and outperformed all other treatments. Additionally, it showed comparable efficacy to tobacco decoction at 2% (10.99%) and azadirachtin at 1500 ppm (11.54%). Citronella oil at 1% (15.98%) was identified as the next most effective treatment, while significantly higher infestation percentages were observed with pongamia oil at 1% (18.08%), custard apple leaf extract at 10% (18.25%), neem oil at 0.5% (18.51%), garlic bulb extract at 5% (18.60%), and jatropha oil at 1% (18.95%).

In the *rabi* season of 2021-22, presented in Table 2, plants treated with neem seed kernel extract at 5% exhibited the lowest damage percentage (9.36%), statistically comparable to tobacco decoction at 2% (10.13%) and azadirachtin at 1500 ppm (10.72%). Citronella oil at 1% (15.10%) emerged as the next most effective treatment. However, significantly higher infestation percentages were recorded for Pongamia oil at 1% (17.22%), custard apple leaf extract at 10% (17.39%), neem oil at 0.5% (17.65%), garlic bulb extract at 5% (17.82%), and jatropha oil at 1% (18.08%).

Based on no. of mines

During the *rabi* season of 2020-21 (Table 3), the plant treated with Neem Seed Kernel Extract at 5% exhibited the lowest damage, recording 11.06 mines per 3 compound leaves, surpassing all other treatments. It performed comparably to tobacco decoction at 2%

(11.26%) and azadirachtin at 1500 ppm (11.40 mines / 3 compound leaves). Following this, citronella oil at 1% (15.58 mines/ 3 compound leaves) emerged as the next effective treatment, trailed by jatropha oil at 1% (16.23 mines/ 3 compound leaves), neem oil at 0.5% (16.31 mines/ 3 compound leaves), garlic bulb extract at 5% (16.39 mines/ 3 compound leaves), custard apple leaf extract at 10% (16.39 mines/ 3 compound leaves), and pongamia oil at 1% (16.97 mines/ 3 compound leaves).

The pooled data over periods and spray for the *rabi* season of 2021-22 (Table 4) reaffirmed the superiority of Neem Seed Kernel Extract at 5%, with the lowest damage recorded at 10.13 mines per 3 compound leaves, surpassing all other treatments. Again, it performed comparably to tobacco decoction at 2% (10.32%) and azadirachtin at 1500 ppm (10.46 mines/ 3 compound leaves). Citronella oil at 1% (14.63 mines/ 3 compound leaves) emerged as the next effective treatment, followed by jatropha oil at 1% (15.18 mines/ 3 compound leaves), neem oil at 0.5% (15.34 mines/ 3 compound leaves), garlic bulb extract at 5% (15.34 mines/ 3 compound leaves), custard apple leaf extract at 10% (15.42 mines/ 3 compound leaves), and pongamia oil at 1% (15.98 mines/ 3 compound leaves). Previous studies have highlighted the efficacy of neem-based treatments in controlling leaf miner populations in various crops, corroborating our findings (Fagoonee and Toory, 1983; Suradkar and Ukey, 2014; Dodiya and Barad, 2022; Mohan and Anitha, 2017; Barde and Shrivastava, 2017). Other biopesticides such as tobacco decoction, azadirachtin, and certain plant extracts have demonstrated effectiveness against similar pests, supporting the present study's outcomes.

Yield

Table 5 presents the data on tomato fruit yield across various botanical treatments and control plots. Remarkably, the highest tomato fruit yield (449.16 q/ha) was obtained from plots treated with neem seed kernel extract at 5%, followed closely by azadirachtin at 1500 ppm (445.83 q/ha) and tobacco decoction at 2% (436.00 q/ha). Citronella oil at 1% also showed promising results, yielding 385.33 q/ha and outperforming the untreated control (285.83 q/ha). Regarding net realization (Table 5), the highest returns were observed in plants treated with neem seed kernel extract at 5% (₹326660), followed by azadirachtin at 1500 ppm (₹320000) and tobacco decoction at 2% (₹300340) and in terms of Profit-Cost Benefit Ratio (PCBR), tobacco decoction at 2% exhibited the highest ratio (1:86.06), followed by neem seed kernel extract at 5% (1:64.01).

CONCLUSION

Neem seed kernel extract at 5% recorded the

Table 5. Economics of botanicals evaluated against leaf miner, *L. trifolii* infesting tomato (Pooled: Rabi, 2020-21 and 2021-22)

Tr. No.	Treatment	Conc. (%)	Total cost of treatment (₹)	Yield (q/ha.)	Gross realization (Rs./ha.)	Net realization (Rs./ha.)	Net gain (Rs./ha.)	PCBR
T ₁	NSKE 5%	5%	5025	449.16	898320	326660	321635	1: 64.01
T ₂	Jatropha oil 1%	1%	3450	314.66	629320	57660	54210	1: 15.71
T ₃	Pongamia oil 1%	1%	3600	319.66	639320	67660	64060	1: 17.79
T ₄	Neem oil 0.5%	0.5%	3000	314.66	629320	57660	54660	1: 18.22
T ₅	Citronella oil 1%	1%	22620	385.33	770660	199000	176380	1: 7.80
T ₆	Custard apple leaf extract 10%	10%	3150	307.00	614000	42340	39190	1: 12.44
T ₇	Azadirachtin 1500 ppm	-	5700	445.83	891660	320000	314300	1: 55.14
T ₈	Garlic bulb extract 5%	5%	5775	320.16	640320	68660	62885	1: 10.89
T ₉	Tobacco decoction 2%	2%	3450	436.00	872000	300340	296890	1: 86.06
T ₁₀	Untreated control	-	-	285.83	571660	0	-	-

NSKE = ₹25/kg Jatropha oil = ₹90/L Pongamia oil = ₹100/L Neem oil = ₹120/L. Citronella oil = ₹1368/L. Azadirachtin = ₹600/L.
 Garlic = ₹35/kg Tobacco dust = ₹10/kg Labour cost = ₹1050/- (Extract preparation: 3 labour) and Rs. 700/- (2 labour/ha for one spray)
 Tomato price = ₹20/kg

lowest damage (9.80%) and it was statistically at par with tobacco decoction at 2% (10.52%) followed by azadirachtin at 1500 ppm (11.13%). Citronella oil at 1% (15.50%) stood the next effective treatment. Similar trend of the treatment effect was noticed for the character no. of mines per three compound leaves. Significantly maximum (449.16 q/ha) tomato fruit yield was harvested from the plots treated with neem seed kernel extract 5% followed by azadirachtin 1500 ppm (445.83 q/ha) and tobacco decoction 2% (436.00 q/ha). The highest PCBR was recorded in the treatment of Tobacco decoction 2% (1: 86.06) followed by NSKE 5% (1: 64.01). Ultimately, the integration of biopesticides into the management paradigm offers a pathway towards sustainable and eco-friendly tomato production under protected cultivation.

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