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Evaluation of different botanicals against fruit damage by chilli gall midge (*Asphondylia capsici*)

Kiran Ghatage, MH Tatagar, Nagesh, Ashoka KS and Dileepkumar A Masuthi

Abstract
The gall midge mainly infests the flower buds and fruits that lead to the deformation of flower buds and fruits resulting in severe flower bud drop, decreasing in fruit size, seed number and finally reduction in yield. Therefore, it is an essential to develop pest management strategies by incorporating various IPM components such as use of organic amendments and botanicals. Among the various botanical management practices against chilli gall midge, in case of fruit damage T_{11} (T_1+ spray with profenofos 50EC @ 2 ml/l) registered its superiority over rest of treatments. The next best treatment is T_5 (T_1+spray with ginger 10% @ 100 g/l) and T_8 (T_1+spray with NSKE 5% @ 100 g/l). However, T_1 (Application of neem cake @ 2.5 q/ha) shows less effectiveness and significantly superior over untreated control. Incorporation of neem cake @ 2.5 q/ha at the time of transplanting followed by spraying NSKE 5% @ 100 g/l coinciding with peak flower bud initiation has recorded highest dry chilli yield of 7.44 q per ha and highest B:C ratio of 2.83 can be recommended as effective and eco- friendly component for the management of chilli gall midge. The highest benefit cost ratio recorded in T_8 (T_1+Spray with NSKE 5% @ 50 g/l) with B:C ratio of 2.83 followed by T_{11} (T_1+Spray with profenofos 50 EC @ 2 ml/l), T_6 (T_1+Spray with Tulsi leaf extract @ 10%), T_3 (T_1+Spray with parthenium leaf extract @ 10%), T_2 (T_1+Spray with Pongamia oil @ 2%), T_1 (Application of Neem cake at 2.5 q/acre), T_4 (T_1+Spray with Garlic extract @ 10%), T_5 (T_1+Spray with Ginger extract @ 10%), T_9 (T_1+Spray with Lemon grass oil @ 10%), T_7 (T_1+Spray with Neem oil @ 3%), T_{10} (T_1+Spray with Citronella oil @ 10%) with benefit cost ratio of 2.69, 2.66, 2.55, 2.54, 2.53, 2.21, 2.10, 1.91, 1.89 and 1.84 respectively.

Keywords: Management, gall, Neem oil, Citronella oil, Botanicals

Introduction
Chilli (*Capsicum annum*) is a most diverse vegetable species and is considered to be high value crop. Which belongs to genus Capsicum, family Solanaceae with chromosome number 2n=24. It is believed that origin of chilli is around 700 BC and origin was Mexico. It is introduced to India through Indonesia and other part of Asia around 400-500 years ago by Portuguese traders (Berke and Sheih, 2000). In this mainly five (5) domestic species are there, *viz., C. pubescns*, *C. baccatum*, *C. chinnensis*, *C. frutenscens* and *C. annum*, which have been described and studied extensively (Smith *et al.* 1987). Among these different domestic species of genus capsicum, *C. annum* is the most widely cultivated genus all over world because of its pungency and pungent (sweet pepper) fruits (Bosland and Votava, 2000) [3]. It is mainly grown in South Africa, New Zeland, Australia, Pakistan and in other Asian countries. Chilli spread from India, through Central Asia and Turkey, to Hungary.It is grown mainly in tropical climatic conditions with ideal temperature of between, 20-25^{0}C and requires the warm climate and loamy soil having high amount of organic content are best suited. In India chilli is a most important commercial cultivated crop for vegetable, spice and industrial (oleoresin and capsicum extraction) purpose (Kumar and Raj, 2005) [4].

India is one of the major chilli producing country in the world which shares 25-26% of dry chilli production and occupies an area of 8.31 lakh with production of 18.72 lakh mt and productivity is 2.25mt per ha in India.

The major chilli growing states includes Andhra Pradesh (49%), Maharashtra (26%), Karnataka (15%), West Bengal (12%) and Tamil Nadu (3%) consisting nearly 75% of total area and production and Andhra Pradesh is the major growing state where area under chilli is 2.06 lakh ha with the production of 8.83 lakh ha under Byadagi variety and other chilli cultivars producing 1.03 lakh MT. Byadagi chilli is one of the most important cultivated farmer's varieties which are mainly grown in different parts of Karnataka *viz.,* Haveri, Dharwad, Gadag. The name Byadagi comes after a town of Byadagi District.

The business of Byadagi chilli has 2nd largest turnover among all chilli variety of India. Chilli blossom midge *(A capsici)* is a serious pest on chilli crop in Maharashtra, Madhya Pradesh, Karnataka, Tamil Nadu and Andhra Pradesh. The extent of loss ranges from 16.3 to 64 per cent (Basavaraj *et al.* 2011) [5]. The gall midge mainly infests the flower buds and fruits that lead to the deformation of flower buds and fruits resulting in severe flower bud drop, decreasing in fruit size, seed number and finally reduction in yield.

Therefore, it is an essential to develop pest management strategies by incorporating various IPM components such as use of organic amendments and botanicals. Keeping these points in view, detail investigations were undertaken.

Materials and Method

The experiment was laid out in a randomized block design with three replications and twelve treatments (Table-1) at HRES, Devihosur during *Kharif* season 2018. The seedlings were raised in nursery bed. Same was used for transplanting during 8 July 2018 with the spacing of 60 x 60 cm with the plot size of 17.28m^2. In each plot ten plants were selected randomly and tagged and observations were recorded on one day before spray and 3, 5, 7 and 11 days after imposition of treatments and all these spray were given at 15 day interval.

Total number of fruits and total number of deformed fruits per plant were recorded, and the total dry chilli yield/plot was recorded. However, before flowering need based spray of profenofos 50EC @ 2 ml/l and imidacloprid 17.8SL @ 0.25 ml/l was taken to manage trips, mites and cut worm. The percentage of galled flower bud was computed by following formulas.

Table 1: Treatment details

Sl. No	Treatments
T_1	Application of Neem cake at 2.5 q/ha
T_2	T_1+ Spray with Pongamia oil @ 2%
T_3	T_1+ Spray with Parthenium leaf extract @ 10%
T_4	T_1+ Spray with Garlic extract @ 10%
T_5	T_1+Spray with Ginger extract @ 10%
T_6	T_1+ Spray with Tulsi leaf extract @ 10%
T_7	T_1+ Spray with Neem oil @ 3%
T_8	T_1+ Spray with NSKE @ 5%
T_9	T_1+ Spray with Lemon grass oil @ 10%
T_{10}	T_1+ Spray with Citronella oil @ 10%
T_{11}	T_1+ Spray with Profenofos 50 EC @ 2 ml/l
T_{12}	Control

$$\text{Per cent damage} = \frac{\text{No of deformed fruits per plant}}{\text{Total no fruits per plant}} \text{ X } 100$$

The mean (%) over control and% increase in yield over control were calculated by using following formula.

$$\text{Reduction over UTC (\%)} = \frac{\text{Control} - \text{Treatment}}{\text{Control}} \text{ X } 100$$

$$\text{Increase in yield (\%)} = \frac{\text{Treatment} - \text{Control}}{\text{Treatment}} \text{ X } 100$$

Results and Discussion

Evaluation of different botanicals against fruit damage by chilli gall midge (*Asphondylia Capsici*)

Efficacy of botanical treatments against chilli gall midge for fruit damage during first spray

The observation was recorded a day before spray and 3, 5, 7 and 11 days after first spray. Before and 3 day after spray observation indicated that there was no significant difference among treatments and mean per cent of fruit damage ranged from 21.26 to 29.92 and 20.68 to 28.82 per cent respectively (Table 2).

Efficacy of botanical treatments against gall midge for fruit damage during first spray at 5 DAS

The observation recorded that, 5 day after spray, among various botanical treatments, incidence of fruit damage was found significantly lowest in T_{11} (20.18%) which was on par with T_5 (21.28%), T_8 (21.55%), T_6 (22.20%), T_4 (22.58%), T_7 (23.28%), T_9 (23.59%), T_2 (25.14%), T_3 (26.25%) and T_{10} (26.64%) and found significantly superior to T_{12} (32.05%) and T_1 (31.50%) (Table 2).

Efficacy of botanical treatments against gall midge for fruit damage during first spray at 7 DAS

The observation recorded that, 7 day after spray, among various botanical treatments, T_5 recorded least per cent of flower bud damage (21.74%) which was statistically on par with T_8 (21.88%), T_{11} (21.90%), T_7 (22.75%), T_6 (22.88%), T_4 (23.42%), T_9 (24.12%), T_{10} (25.42%), T_2 (25.88%) and T_3 (25.87%) and found significantly superior to T_{12} (36.35%) (Table 2).

Table 2: Efficacy of different treatments against chilli gall midge for fruit damage after first spray during *Kharif* 2018-19

Treatment No	Treatment details	Dosage	1 DBS	Fruit damage (%)					
				3 DAS	5 DAS	7 DAS	11 DAS	Mean	Reduction in gall midge over UTC (%)
T_1	Application of Neem cake	2.5q/ha	29.92 (33.13)	26.2 (33.89)	31.5 (34.52)^a	33.69 (35.47)^a	33.9 (35.64)^{ab}	31.32 (34.90)^{ab}	6.39
T_2	T_1+ Spray with Pongamia oil @ 2%	2.5q/ha+20ml/l	23.12 (28.68)	23.49 (28.91)	25.14 (29.95)^{ab}	25.88 (30.46)^b	26.73 (31.02)^{bcd}	25.31 (30.09)^{cd}	24.37
T_3	T_1+ Spray with Parthenium leaf extract @ 10%	2.5q/ha+100g/l	25.28 (30.15)	25.28 (30.15)	26.25 (30.78)^{ab}	25.87 (30.54)^b	26.25 (30.78)^{cd}	25.92 (30.56)^{bcd}	22.56
T_4	T_1+ Spray with Garlic extract @ 10%	2.5q/ha+100g/l	22.82 (28.44)	22.25 (28.04)	22.58 (28.08)^b	23.42 (28.77)^b	23.61 (28.90)^{cd}	22.97 (28.46)^{cd}	31.37
T_5	T_1+ Spray with Ginger extract @ 10%	2.5 q/ha+100 g/l	21.56 (27.59)	21.56 (27.59)	21.28 (27.40)^b	21.74 (27.75)^b	22.24 (28.08)^d	21.71 (27.71)^{cd}	35.14
T_6	T_1+ Spray with Tulsi leaf extract @ 10%	2.5 q/ha+100 g/l	21.97 (27.92)	21.97 (27.92)	22.20 (28.07)^b	22.88 (28.53)^b	23.61 (29.01)^{cd}	22.66 (28.39)^{cd}	32.27
T_7	T_1+ Spray with Neem oil @ 3%	2.5 q/ha+30	24.00	23.75	23.28	22.75	23.11	23.22	30.61

		ml/l	(29.30)	(29.14)	(28.83)^{b}	(28.47)^{b}	(28.71)^{cd}	(28.80)^{cd}	
T_8	T_1+ Spray with NSKE @ 5%	2.5 q/ha+50 g/l	23.15 (28.69)	23.15 (28.69)	21.55 (27.63)^{b}	21.88 (27.87)^{b}	21.59 (27.68)^{d}	22.04 (27.98)^{cd}	34.13
T_9	T_1+ Spray with Lemon grass oil @ 10%	2.5 q/ha+100 ml/l	23.71 (28.99)	23.71 (28.99)	23.59 (28.92)^{b}	24.12 (29.28)^{b}	24.41 (29.48)^{cd}	23.96 (29.17)^{cd}	28.40
T_{10}	T_1+ Spray with Citronella oil @ 10%	2.5 q/ha+100 ml/l	29.43 (32.73)	27.5 (32.73)	26.64 (31.05)^{ab}	25.42 (30.27)^{b}	30.17 (33.27)^{abc}	27.43 (31.87)^{abc}	18.02
T_{11}	T_1+Spray with Profenofos 50 EC @ 2 ml/l	2.5 q/ha+2 ml/l	21.26 (27.45)	20.68 (27.04)	20.18 (26.69)^{b}	21.90 (27.88)^{b}	21.97 (27.90)^{d}	21.18 (27.40)^{d}	36.70
T_{12}	Control	–	26.37 (30.88)	28.82 (32.44)	32.05 (34.47)^{a}	36.35 (37.05)^{a}	36.62 (37.20)^{d}	33.46 (35.31)^{a}	–
S.Em±			-	-	1.60	1.43	1.65	1.51	
CD at 5%			NS	NS	4.70	4.19	4.84	4.42	
CV (%)			9.83	9.91	9.36	8.20	9.23	8.70	

* Figures in the parentheses are arc sin transformed values
* Figures with same alphabetical superscript are statistically non-significant

Efficacy of botanical treatments against gall midge for fruit damage during first spray at 11 DAS

The observation recorded that, 11 day after spray, among various botanical treatments, T_8 recorded least per cent of fruit damage (21.59%) which was statistically on par with T_{11} (21.97%), T_5 (22.24%), T_7 (23.11%), T_4 (23.61%), T_6 (23.61%), T_9 (24.41%), T_3 (26.25%) and T_2 (26.73%) and found significantly superior to T_{10} (30.17%), T_1 (33.90%) and T_{12} (36.62%) (Table 2).

Mean efficacy of botanical treatments during first spray against gall midge for fruit damage indicated that T_{11} (T_1+spray with profenofos 50EC @ 2 ml/l) (21.18%) recorded least fruit damage with highest per cent reduction (36.70%) in fruit damage over untreated control. The next best treatment is T_5 (T_1+spray with ginger 10% @ 100g/l) (21.71%) which was statistically on par with T_8 (22.04%), T_6 (22.66%), T_4 (22.97%), T_9 (23.96%), T_2 (25.31%) and T_3 (25.92%) and found significantly superior over T_{10} (27.43%) and T_{12} (33.46 5) and found inferior to T_{11} (21.18%). Treatment T_{12} recorded highest per cent fruit damage (33.46%) and treatment T_1 recorded lowest per cent reduction in fruit damage (6.39%) over untreated control (Table 2).

Efficacy of botanical treatments against chilli gall midge for fruit damage during second spray

Pre-treatment and 3 days after spray indicated that there was no significant difference among treatments and mean per cent fruit damage ranged from 18.00 to 28.16 and 18.12 to 29.89 per cent respectively (Table 3).

Table 3: Efficacy of different treatments against chilli gall midge for fruit damage after second spray during *Kharif* 2018-19

Treatment No.	Treatments details	Dosage	1 DBS	Fruit damage (%)					
				3 DAS	5 DAS	7 DAS	11 DAS	Mean	Reduction in gall midge over UTC (%)
T_1	Application of Neem cake	2.5q/ha	25.22 (30.13)	25.54 (30.33)	26.24 (30.79)^{ab}	25.70 (30.43)^{b}	24.55 (29.68)^{b}	25.51 (30.32)^{b}	23.67
T_2	T_1+ Spray with Pongamia oil @ 2%	2.5q/ha+20ml/l	23.57 (28.91)	24.07 (29.23)	23.29 (28.74)^{bc}	22.45 (28.17)^{bc}	21.48 (27.51)^{b}	22.82 (28.43)^{bc}	31.70
T_3	T_1+ Spray with Parthenium leaf extract @ 10%	2.5q/ha+100g/l	22.02 (27.86)	22.33 (28.07)	22.16 (27.94)^{bc}	21.64 (27.59)^{bc}	19.78 (26.30)^{b}	21.48 (27.49)^{bc}	35.72
T_4	T_1+ Spray with Garlic extract @ 10%	2.5q/ha+100g/l	20.11 (26.63)	19.02 (25.81)	19.34 (26.07)^{bc}	19.93 (26.51)^{bc}	19.90 (26.48)^{b}	19.55 (26.23)^{bc}	41.50
T_5	T_1+ Spray with Ginger extract @ 10%	2.5q/ha+100g/l	18.41 (25.40)	18.30 (25.13)	18.24 (25.27)^{bc}	18.48 (25.44)^{c}	18.00 (25.09)^{b}	18.25 (25.28)^{c}	45.37
T_6	T_1+ Spray with Tulsi leaf extract @ 10%	2.5q/ha+100g/l	21.15 (27.34)	22.36 (26.45)	20.53 (26.89)^{bc}	19.81 (26.38)^{bc}	19.18 (25.92)^{b}	20.47 (26.85)^{bc}	38.74
T_7	T_1+ Spray with Neem oil @ 3%	2.5q/ha+30ml/l	19.87 (26.45)	19.87 (26.45)	19.55 (26.22)^{bc}	18.61 (25.53)^{c}	18.29 (25.30)^{b}	19.08 (25.89)^{bc}	42.91
T_8	T_1+ Spray with NSKE @ 5%	2.5q/ha+50g/l	19.15 (25.89)	20.07 (26.53)	15.94 (23.51)^{c}	17.85 (24.93)^{c}	17.88 (24.95)^{b}	18.60 (25.49)^{c}	44.33
T_9	T_1+ Spray with Lemon grass oil @ 10%	2.5q/ha+100ml/l	20.77 (27.02)	21.02 (27.21)	19.95 (26.40)^{bc}	20.73 (27.03)^{bc}	19.81 (26.35)^{b}	20.38 (26.76)^{bc}	39.02
T_{10}	T_1+ Spray with Citronella oil @ 10%	2.5q/ha+100ml/l	22.09 (27.93)	25.15 (30.00)	21.54 (27.55)^{bc}	21.08 (27.23)^{bc}	20.88 (27.12)^{b}	22.16 (28.02)^{bc}	33.67
T_{11}	T_1+Spray with Profenofos 50 EC @ 2 ml/l	2.5q/ha+2ml/l	18.00 (25.04)	18.12 (25.13)	17.75 (24.85)^{bc}	17.37 (24.57)^{c}	18.32 (25.30)^{b}	17.89 (24.97)^{c}	46.46
T_{12}	Control	–	28.16 (32.02)	29.89 (33.10)	35.77 (36.46)^{a}	34.95 (36.21)^{a}	33.05 (34.94)^{a}	33.41 (35.22)^{a}	–
S.Em±			_	_	2.21	1.46	1.63	1.63	
CD at 5%			NS	NS	6.50	4.30	4.80	4.78	
CV (%)			9.79	10.44	13.92	9.25	10.47	10.25	

* Figures in the parentheses are arc sin transformed values
* Figures with same alphabetical superscript are statistically non-significant

Efficacy of botanical treatments against gall midge for fruit damage during second spray at 5 DAS

The observation recorded that, 5 day after spray, among various botanical treatments, T_8 recorded lowest incidence of fruit damage (15.94%) which was on par with T_{11} (17.75%), T_5 (18.24%), T_4 (19.34%), T_7 (19.55%), T_9 (19.95%), T_6 (20.53%), T_{10} (21.54%), T_3 (22.16%) and T_2 (23.29%) and found significantly superior to T_1 (26.24%) and T_{12} (35.77%) (Table 3).

Efficacy of botanical treatments against gall midge for fruit damage during second spray at 7 DAS

The observation recorded that, 7 day after spray, among various botanical treatments, T_{11} recorded least per cent of fruit damage (17.37%) which was statistically on par with T_8 (17.85%), T_5 (18.48%), T_7 (18.61%), T_6 (19.81%), T_4 (19.93%), T_9 (20.73%), T_{10} (21.08%), T_3 (21.64%) and T_2 (24.45%) and found significantly superior to T_1 (25.70%) and T_{12} (34.95%) (Table 3).

Efficacy of botanical treatments against gall midge for fruit damage during second spray at 11 DAS

The observation recorded that, 11day after spray, among various botanical treatments, T_8 recorded least per cent fruit damage (17.88%) which was statistically on par with T_5 (18.00%), T_{11} (18.32%), T_6 (19.18%), T_3 (19.78%), T_9 (19.81%), T_4 (19.90%), T_{10} (20.88%), T_2 (21.48%) and T_1 (24.55%) and found significantly superior to T_{12} (33.05%) (Table 3).

Mean efficacy of botanical treatments during second spray against gall midge for fruit damage indicated that T_{11} (T_1+Spray with profenofos 50EC @ 2ml/l) (17.89%) recorded least per cent fruit damage with highest per cent reduction (46.46%) in fruit damage over untreated control. The next best treatment is T_5 (T_1+Spray with ginger 10% @ 100 g/l) (18.25%) which was statistically on par with T_8 (18.60%), T_7 (19.08%), T_4 (19.55%), T_9 (20.38%), T_6 (20.47%), T_3 (21.48%) T_{10} (22.16%) and T_2 (22.82%) and found inferior to T_{11} (17.89%) and found significantly superior to T_1 (25.51%) and T_{12} (33.41%). Treatment T_{12} recorded highest per cent fruit damage (33.41%) and treatment T_1 recorded lowest per cent reduction in fruit damage (23.67%) over untreated control (Table 3).

Efficacy of botanical treatments against chilli gall midge for fruit damage during third spray: Pre-treatment and 3 days after spray observation indicated that there was no significant difference among treatments and mean per cent fruit damage ranged from 17.45 to 29.16 and 14.42 to 24.00 per cent respectively (Table 4).

Efficacy of botanical treatments against gall midge for fruit damage during third spray at 5 DAS

At 5 DAS, the incidence of fruit damage was found significantly lowest in T_8 (14.42%) which was on par with T_{11} (17.57%), T_5 (18.60%), T_6 (19.04%), T_7 (19.53%), T_9 (19.86%) and found significantly superior to T_4 (20.61%), T_{10} (20.70%), T_3 (21.24%), T_2 (22.08 T_1 (27.08%) and T_{12} (31.56%) (Table 4).

Efficacy of botanical treatments against gall midge for fruit damage during third spray at 7 DAS

The observation recorded that, 7 day after spray, among various botanical treatments, T_{11} recorded least per cent flower bud damage (18.86%) which was statistically on par with T_5 (18.91%), T_7 (19.67%), T_9 (19.72%), T_6 (20.42%), T_4 (20.72%), T_8 (20.98%),T_3 (21.53%),T_{10} (21.46%), T_2 (22.70%) and found significantly superior to T_1 (26.37%) and T_{12} (30.49%), (Table 4).

Efficacy of botanical treatments against gall midge for fruit damage during third spray at 11 DAS

The observation recorded that 11 day after spray, among various botanical treatments, T_8 recorded least per cent fruit damage (19.05%) which was statistically on par with T_5 (19.22%), T_7 (19.69%), T_9 (20.70%), T_6 (20.85%), T_4 (20.97%), T_3 (21.20%), T_8 (21.14%) T_{10} (21.56%), T_2 (23.15%) and found significantly superior to T_1 (27.23%) and T_{12} (35.38%) (Table 4).

Mean efficacy of botanical treatments during third spray against gall midge for fruit damage indicated that T_{11} (T_1+spray with profenofos 50EC @ 2ml/l) (18.35%) recorded least per cent fruit damage with highest per cent reduction (39.55%) in fruit damage over untreated control. The next best treatment is T_5 (T_1+spray with ginger 10% @ 100g/l) (18.84%) which was statistically on par with T_7 (19.72%), T_9 (19.76%), T_6 (20.08%), T_4 (19.64%), T_3 (21.55%), T_{10} (21.59%), T_2 (22.10%) and found inferior to T_{11} (18.35%). Treatment T_{12} recorded highest per cent fruit damage (30.36%) and treatment T_1 recorded lowest per cent reduction in fruit damage (13.96%) over untreated control (Table 4).

Table 4: Efficacy of different treatments against chilli gall midge for fruit damage after third spray during *Kharif* 2018-19

Treatment No.	Treatments details	Dosage	1 DBS	Fruit damage (%)					
				3 DAS	5 DAS	7 DAS	11 DAS	Mean	Reduction in gall midge over UTC (%)
T_1	Application of Neem cake	2.5q/ha	21.86 (28.41)	23.79 (29.18)	27.08 (31.31)^{ab}	26.37 (30.86)^{ab}	27.23 (31.40)^{b}	26.12 (30.96)^{ab}	13.96
T_2	T_1+ Spray with Pongamia oil @ 2%	2.5q/ha+20ml/l	21.31 (28.01)	20.45 (26.86)	22.08 (27.95)^{abc}	22.70 (28.35)^{bc}	23.15 (28.68)^{bc}	22.10 (28.26)^{bc}	27.20
T_3	T_1+ Spray with Parthenium leaf extract @ 10%	2.5q/ha+100g/l	21.31 (27.43)	22.25 (28.13)	21.24 (27.39)^{bc}	21.53 (27.58)^{bc}	21.20 (27.31)^{c}	21.55 (27.33)^{bc}	29.01
T_4	T_1+ Spray with Garlic extract @ 10%	2.5q/ha+100g/l	20.22 (26.70)	16.26 (23.65)	20.61 (26.96)^{bc}	20.72 (27.04)^{bc}	20.97 (27.20)^{c}	19.64 (26.96)^{c}	35.30
T_5	T_1+ Spray with Ginger extract @ 10%	2.5q/ha+100g/l	19.22 (25.99)	18.68 (25.46)	18.60 (25.54)^{bcd}	18.91 (25.77)^{c}	19.22 (26.00)^{c}	18.84 (25.80)^{c}	37.94
T_6	T_1+ Spray with Tulsi leaf extract @ 10%	2.5q/ha+100g/l	19.19 (25.96)	20.03 (26.38)	19.04 (25.86)^{bcd}	20.42 (26.85)^{bc}	20.85 (27.16)^{c}	20.08 (26.54)^{c}	33.86
T_7	T_1+ Spray with Neem oil @ 3%	2.5q/ha+30ml/l	19.44	19.99	19.53	19.67	19.69	19.72	35.04

			(26.15)	(26.50)	(26.21)^{bcd}	(26.29)^{c}	(26.32)^{c}	(26.29)^{c}	
T_8	T_1+ Spray with NSKE @ 5%	2.5q/ha+50g/l	19.54 (26.78)	19.59 (26.25)	14.42 (20.67)^{d}	20.98 (27.23)^{bc}	21.14 (27.36)^{c}	19.03 (25.93)^{c}	37.31
T_9	T_1+ Spray with Lemon grass oil @ 10%	2.5q/ha+100ml/l	19.54 (26.15)	18.77 (25.65)	19.86 (26.40)^{bcd}	19.72 (26.3)^{c}	20.70 (27.03)^{c}	19.76 (26.40)^{c}	34.91
T_{10}	T_1+ Spray with Citronella oil @ 10%	2.5q/ha+100ml/l	20.94 (27.22)	22.64 (28.29)	20.70 (27.06)^{bc}	21.46 (27.59)^{bc}	21.56 (27.66)^{bc}	21.59 (27.38)^{bc}	28.88
T_{11}	T_1+Spray with Profenofos 50 EC @ 2 ml/l	2.5q/ha+2ml/l	17.45 (24.63)	17.92 (24.90)	17.57 (24.71)^{cd}	18.86 (25.61)^{c}	19.05 (25.75)^{c}	18.35 (25.33)^{c}	39.55
T_{12}	Control	–	29.16 (32.62)	24.00 (29.23)	31.56 (34.14)^{a}	30.49 (33.44)^{a}	35.38 (36.49)^{a}	30.36 (34.45)^{a}	–
S.Em±			-	-	2.12	1.43	1.32	1.23	
CD at 5%			NS	NS	6.20	4.21	3.88	3.61	
CV (%)			8.43	7.96	13.65	8.96	8.12	7.76	

* Figures in the parentheses are arc sin transformed values
* Figures with same alphabetical superscript are statistically non-significant

Efficacy of different botanical treatments against chilli gall midge for fruit damage during 2018-19

Mean fruit bud damage after 3 spray it was found that T_{11} (T_1+Spray with Profenofos 50EC @ 2ml/l) recorded lowest (12.85%) fruit damage and these findings are due to it exhibits ovicide cum adulticide, fast knock down action with long residual activity and less waiting period between last spray and harvest. Hence the incidence of gall midge on flower bud less in chilli. The present results are in agreement with Archana (2011) [6] reported that the effectiveness of profenofos 50EC on gall midge and recorded 8.59 per cent of gall midge damage. Next best treatment T_5 (T_1 + Spray with ginger 10% @ 100g/l) (19.60%) and these findings are due to per cent hatchability of deposited eggs were significantly decreases, pupation per cent, ratio of adult emergence, sex ratio and female fecundity get reduced. This treatment which was on par with T_8 (19.84%), T_4 (20.72%), T_7 (20.63%), T_6 (21.17%), T_9 (21.97%), T_3 (23.10%), T_2 (23.37%), T_{10} (24.34%) and found significantly superior to T_1 (28.78%) and T_{12} (32.41%). The present results are in agreement with Omara *et al.* (1996) [7] recorded the effectiveness of ANSKP @ 4% reduced the number of *Liriomyza congest* by 79.48% and *Aphis craccivora* by 52.39% in 1993-1994 respectively. Krishnakumar *et al.* 2010, reported that management of gall midge, *Asphondylia capsici* on chilli and brinjal with application of neem cake followed by spray with NSKE 4% as most effective treatment. Chandrashekaran *et al.* (1998) reported that, a chook 1.5 per cent recorded 72.9 per cent reduction of trips population followed by neem oil 5 per cent (60.1%). Veena *et al.* (2018) [10] reported that crop planting with Neem cake (250kg/ha) and vermicompost (1t/ha) were effective in suppression of gall midge infesting chilli crop, as comparable to recommended insecticides. Pongamia cake (250kg/ha) was next in the order of effectiveness. Shivaramu (1999) reported effectiveness of neem oil @ 5 ml/l, NSKE 5% and a chook @ 5ml/l recorded 12.99, 9.77 and 96 per cent of fruit damage. Singh *et al.* (1999) observed the effectiveness of garlic, neem, and tagak-tagak (*Rhinocanthus nusuta*) on chilli against aphids, neem extract @ 5000 ppm recorded low aphid population as compared with unsprayed control, malathion. Which was significantly differ with T_5 (18.03%), T_4 (18.91%), T_7 (18.98%), T_9 (19.15%), T_6 (20.81%), T_2 (21.83%), T_{10} (22.38%), T_1 (23.92%) and T_{12} (38.49%) flower bud damage. The present results are in agreement with Vijayalakshmi *et al.* (1996) [13] indicated that application of garlic extract in combination with cow urine, chilli, neem, ginger with soap solution was effective against *S. Litura* and *H. armigera* up to 13 days of spray. Fathima *et al.* (2015) reported that application of red chilli and garlic extract reduced the mite population and also helps to increase the yield. Whereas effectiveness of T_7 (T_1 + spray with neem oil 3% @ 30ml/l) is in conformity with reports of Ahmed *et al.* (2001) reported that the application of neem oil at 5ml/l that helps to reduced chilli mite populations to 34.28 per cent over control. Kumar *et al.* (2017) [15] reported that treatment with application of NSKE, neem oil and garlic sap extract 53.03, 55.64 and 50.03 per cent reduction in trips population respectively. Whereas, effectiveness of T_2 (T_1 + Spray with pongamia oil 2% @ 20ml/l) is in conformity with the reports of Meena and Tayde (2017) reported use of imidacloprid, neem oil, pongamia oil, NSKE and garlic sap extract registered 67.58, 53.03, 55.4, and 50.03 per cent and reduction in trips population. Whereas T_1 (application of neem cake 2.5 q/ha) is in conformity with results of Chandramani (2010) [17], reported application of FYM + neem cake in splits significantly reduced the incidence of gall former (66.81%). The per cent reduction in gall midge over untreated control recorded highest in T_{11} (40.08%) and T_5 (39.52%), lowest per cent reduction recorded in T_1 (11.20%) over untreated control and remaining treatments *viz.*, T_8 (38.63%), T_7 (36.34%), T_4 (36.09%), T_6 (34.68%), T_{10} (33.15%), T_9 (32.21%), T_3 (28.72%) and T_2 (27.89%) showed moderate per cent reduction in gall midge over untreated (Table 5 and Fig 1).

Fruit yield (q/ha)

Based on the observations recorded on dry chilli yield, it was found that, significant difference was recorded and it ranged from 4.29q/ha to 7.44 q/ha. Among various treatments, T_8 (T_1+ Spray with NSK 5% @ 50g/l) recorded maximum yield in (7.44q/ha) and these results are in conformity with Gasukar (2011) reported NCE (5%) or NO (1%) recorded highest chilli yield.

Table 5: Efficacy of different treatments against chilli gall midge for fruit damage and dry chilli fruit yield during 2018-19

Treatment		Dosage	I spray		II spray		III spray		Average		Dry fruit yield (q/ha)	Increase in yield over UTC (%)
No.	Details		Gall midge damage	Reduction in gall midge over UTC (%)	Gall midge damage	Reduction in gall midge over UTC (%)	Gall midge damage	Reduction in gall midge over UTC (%)	Gall midge damage	Reduction in gall midge over UTC (%)		
T_1	Application of Neem cake	2.5q/ha	31.32 (34.90)^{ab}	6.39	25.51 (30.32)^{b}	23.67	26.12 (30.96)^{ab}	13.96	28.78 (32.44)^{ab}	11.20	6.59^{de}	34.90
T_2	T_1+Spray with Pongamia oil @ 2%	2.5 q/ha+ 20 ml/l	25.31 (30.09)^{cd}	24.37	22.82 (28.43)^{bc}	31.70	22.10 (28.26)^{bc}	27.20	23.37 (28.81)^{bc}	27.89	7.14^{ab}	39.91
T_3	T_1+ Spray with Parthenium leaf extract @ 10%	2.5 q/ha+ 100 g/l	25.92 (30.56)^{bcd}	22.56	21.48 (27.49)^{bc}	35.72	21.55 (27.33)^{bc}	29.01	23.10 (28.67)^{bc}	28.72	6.48^{e}	33.79
T_4	T_1+ Spray with Garlic extract @ 10%	2.5 q/ha+ 100 g/l	22.97 (28.46)^{cd}	31.37	19.55 (26.23)^{bc}	41.50	19.64 (26.96)^{c}	35.30	20.72 (26.68)^{c}	36.09	7.04^{bc}	39.06
T_5	T_1+ Spray with Ginger extract @ 10%	2.5 q/ha+ 100 g/l	21.71 (27.71)^{cd}	35.14	18.25 (25.28)^{c}	45.37	18.84 (25.80)^{c}	37.94	19.60 (26.16)^{c}	39.52	6.74^{cde}	36.35
T_6	T_1+ Spray with Tulsi leaf extract @ 10%	2.5 q/ha+ 100 g/l	22.66 (28.39)^{cd}	32.27	20.47 (26.85)^{bc}	38.74	20.08 (26.54)^{c}	33.86	21.17 (27.32)^{c}	34.68	6.75^{cde}	36.44
T_7	T_1+ Spray with Neem oil @ 3%	2.5 q/ha+ 30 ml/l	23.22 (28.80)^{cd}	30.61	19.08 (25.89)^{bc}	42.91	19.72 (26.29)^{c}	35.04	20.63 (27.01)^{c}	36.34	7.38^{a}	41.86
T_8	T_1+ Spray with NSKE @ 5%	2.5 q/ha+ 50 g/l	22.04 (27.98)^{cd}	34.13	18.60 (25.49)^{c}	44.33	19.03 (25.93)^{c}	37.31	19.89 (26.61)^{c}	38.63	7.44^{a}	42.33
T_9	T_1+ Spray with Lemon grass oil @ 10%	2.5 q/ha+ 100 ml/l	23.96 (29.17)^{cd}	28.40	20.38 (26.76)^{bc}	39.02	19.76 (26.40)^{c}	34.91	21.97 (27.84)^{c}	32.21	6.90^{bcd}	37.82
T_{10}	T_1+ Spray with Citronella oil @ 10%	2.5 q/ha+ 100 ml/l	27.43 (31.87)^{abc}	18.02	22.16 (28.02)^{bc}	33.67	21.59 (27.38)^{bc}	28.88	24.34 (29.54)^{bc}	33.15	6.76^{cde}	36.53
T_{11}	T_1+Spray with Profenofos 50 EC @ 2 ml/l	2.5 q/ha+2 ml/l	21.18 (27.40)^{d}	36.70	17.89 (24.97)^{c}	46.46	18.35 (25.33)^{c}	39.55	19.42 (26.11)^{c}	40.08	7.19^{ab}	40.33
T_{12}	Control	–	33.46 (35.31)^{a}	–	33.41 (35.22)^{a}	–	30.36 (34.45)^{a}	–	32.41 (34.74)^{a}	–	4.29^{f}	–
S.Em±			1.51		1.51		1.63		1.23		0.11	
CD at 5%			4.42		4.42		4.78		3.61		0.33	
CV (%)			8.70		8.70		10.25		7.76		2.97	

* Figures in the parentheses are arc sin transformed values
* Figures with same alphabetical superscript are statistically non-significant

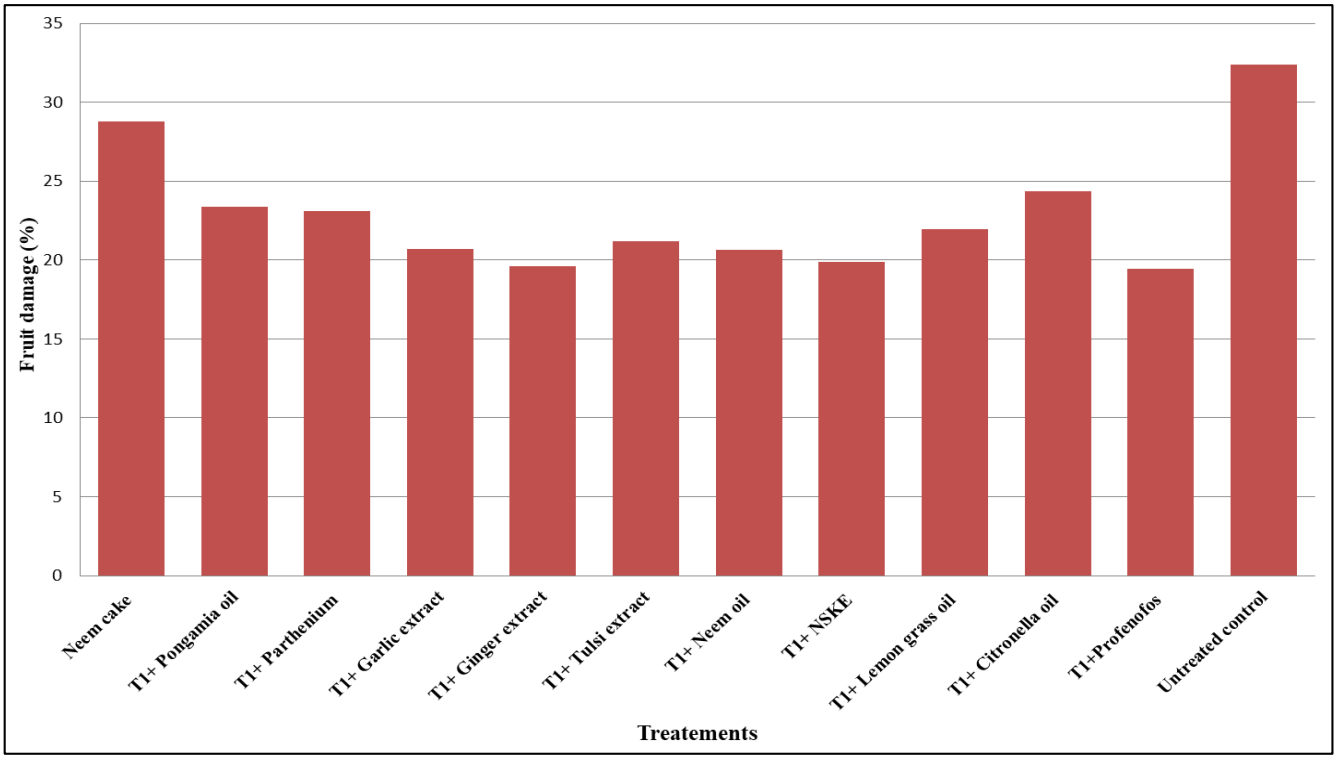

Fig 1: Effect of botanical spray on chilli for fruit damage during *Kharif* 2018-19

Ogan and Ogbodo (2012) [19] reported that application of NSKE could help in management of African rice gall midge and also increase yield without the disruption of agro-ecosystem, followed T_7 (T_1+ Spray with Neem oil 3% @ 30ml/l) (7.38q/ha) which is followed by T_{11} (7.19q/ha), T_2 (7.14q/ha), T_4 (7.04q/ha), T_9 (6.90q/ha), T_{10} (6.76q/ha), T_6 (6.75q/ha), T_5 (6.74q/ha), T_1 (6.59q/ha), T_3 (6.48q/ha) and it was lowest in untreated control T_{12} (4.29 q/ha) (Table 5 and Fig 2).

Similarly, treatment T_8 (T_1+Spray with NSKE 5% @ 50g/l) recorded significantly highest per cent increase in yield over untreated control 42.33 per cent which was followed by treatments T_7 (41.86%), T_{11} (40.33%), T_2 (39.91%), T_4 (39.06%), T_9 (37.82%), T_{10} (36.53%), T_6 (36.44%), T_5 (36.35%), T_1 (34.90%) and T_3 (33.79%) yield increase over control (Table 5).

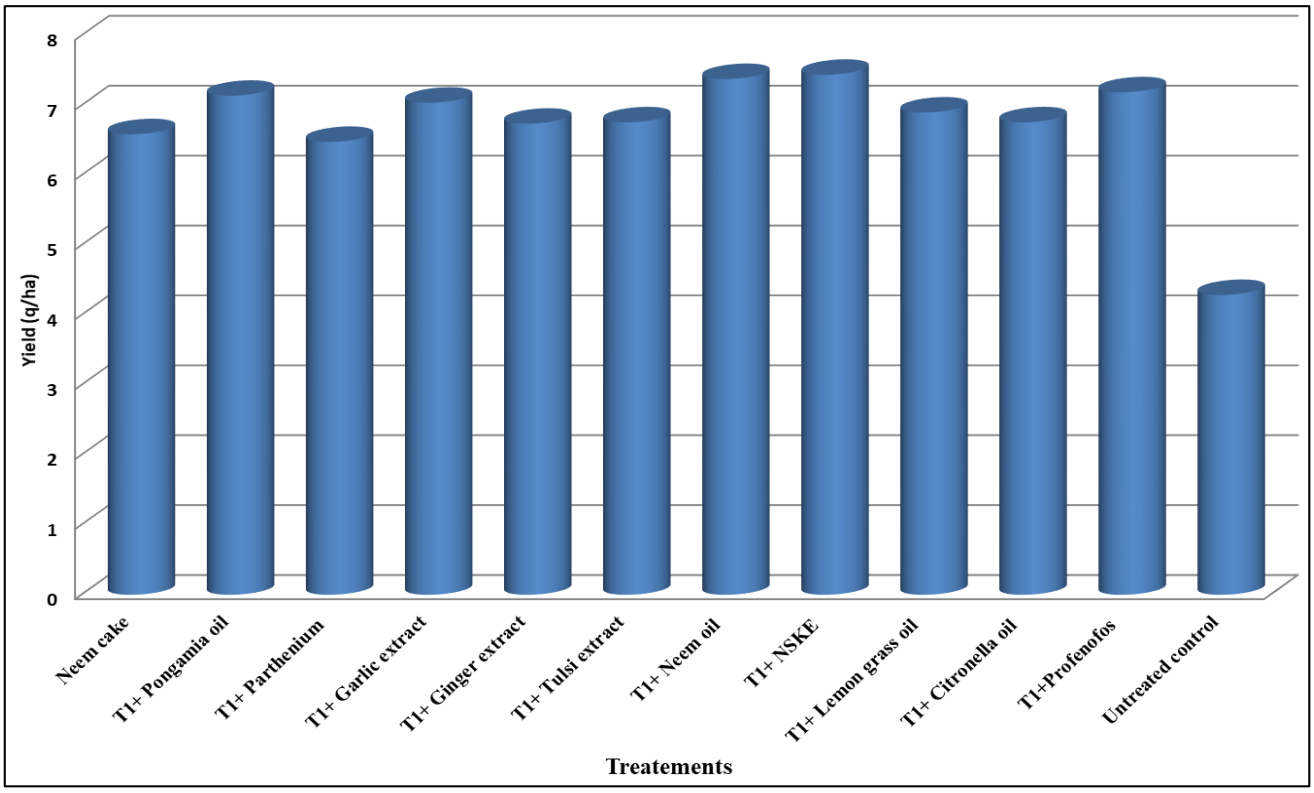

Fig 2: Effect of botanical spray on dry chilli fruit yield during *Kharif* 2018-19

Economics of various botanical treatments for the management of chilli gall midge during 2018-19

The observation recorded that, among various botanical treatments, highest net return recorded in treatment T_8 (T_1+ Spray with NSK 5% @ 50g/l) (Rs. 72298/h) in comparison to all other treatments *viz.*, T_{11} (T_1+Spray with Profenofos 50 EC @ 2ml/l) (Rs. 67850/h), T_2 (T_1+Spray with Pongamia oil @ 2%) (Rs. 65160/h), T_6 (T_1+Spray with Tulsi leaf extract @ 10%) (Rs. 63400/h), T_1 (Application of Neem cake at 2.5 q/acre) (Rs. 59787/h), T_3 (T_1+Spray with Parthenium leaf extract @ 10%) (Rs. 59200/h), T_4 (T_1+Spray with Garlic extract @ 10%) (Rs. 57934/h), T_5 (T_1+Spray with Ginger extract @ 10%) (Rs. 54736/h), T_7 (T_1+ Spray with Neem oil @ 3%) (Rs. 52296/h), T_9 (T_1+ Spray with Lemon grass oil @ 10%) (Rs. 49455/h), T_{10} (T_1+ Spray with Citronella oil @ 10%) (Rs. 46458/h) and untreated control (Rs. 29350/h).

The highest benefit cost ratio recorded in T_8 (T_1+Spray with NSKE 5% @ 50g/l) with B:C ratio of 2.83 followed by T_{11} (T_1+Spray with profenofos 50 EC @ 2ml/l), T_6 (T_1+Spray with Tulsi leaf extract @ 10%), T_3 (T_1+Spray with parthenium leaf extract @ 10%), T_2 (T_1+Spray with Pongamia oil @ 2%), T_1 (Application of Neem cake at 2.5q/acre), T_4 (T_1+Spray with Garlic extract @ 10%), T_5 (T_1 + Spray with Ginger extract @ 10%), T_9 (T_1+Spray with Lemon grass oil @ 10%), T_7 (T_1+Spray with Neem oil @ 3%), T_{10} (T_1+Spray with Citronella oil @ 10%) with benefit cost ratio of 2.69, 2.66, 2.55, 2.54, 2.53, 2.21, 2.10, 1.91, 1.89 and 1.84 respectively (Table 6).

Table 6: Economics of various treatments for the management of chilli gall midge during *Kharif* 2018-19

Treatment details	Dosage	Dry fruit yield (q/ha)	Cost of plant protection (Rs/ha)	Total cost of plant production (Rs/ha)	Gross return (Rs/ha)	Net return (Rs/ha)	B:C Ratio
Application of Neem cake	2.5 q/ha	6.59	4063	39063	98850	59787	2.53
T_1+ Spray with Pongamia oil @ 2%	2.5q/ha+20ml/l	7.14	6595	41595	107100	65505	2.57
T_1+ Spray with Parthenium leaf extract @ 10%	2.5q/ha+100g/l	6.48	3000	38000	97200	59200	2.55
T_1+ Spray with Garlic extract @ 10%	2.5q/ha+100g/l	7.04	12666	47666	105600	57934	2.21
T_1+ Spray with Ginger extract @ 10%	2.5q/ha+100g/l	6.74	11364	46364	101100	54736	2.10
T_1+ Spray with Tulsi leaf extract @ 10%	2.5q/ha+100g/l	6.76	3000	38000	101400	63400	2.66
T_1+ Spray with Neem oil @ 3%	2.5q/ha+30ml/l	7.38	23400	58404	110700	52296	1.89
T_1+ Spray with NSKE @ 5%	2.5q/ha+50g/l	7.44	4302	39302	111600	72298	2.83
T_1+ Spray with Lemon grass oil @ 10%	2.5q/ha+100ml/l	6.90	19045	54045	103500	49455	1.91
T_1+ Spray with Citronella oil @ 10%	2.5q/ha+100ml/l	6.76	30942	54942	101400	46458	1.84
T_1+Spray with Profenofos 50 EC @ 2 ml/l	2.5q/ha+2ml/l	7.19	5000	40000	107850	67850	2.69
Control	_	4.29	0.00	35000	64350	29350	1.83

Market price: Rs.15000/q, B: C ratio = Gross returns/Total cost of production

Gross return = Yield × Market price, Net returns = Gross returns – Total cost of production

Conclusion

Among the various management practices evaluated against chilli gall midge, in case of fruit damage, treatment, T_{11} (T_1+Spray with profenofos 50EC @ 2ml/l) registered its superiority over rest of treatment and the next best treatment is T_5 (T_1+Spray with ginger 10% @ 100g/l), T_8 (T_1+Spray with NSKE 5% @ 50g/l) and T_7 (T_1+ Spray with neem oil 3% @ 30ml/l) by recording for fruit damage and highest dry chilli yield recorded in T_8 (T_1+Spray with NSKE 5% @50g/l) of 7.44q/ha with B:C of 2.83. Hence among various treatments, T_8 (T_1+Spray with NSKE 5% @ 50g/l) can be recommended as effective and eco-friendly component for the management of chilli gall midge.

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