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RESEARCH ARTICLE

PESTICIDAL EFFECT OF SELECTED PLANT EXTRACTS ON *Polyphagotarsonemus latus* (BANKS) INFESTATION IN *Corchorus olitorius* L. JUTE

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ABSTRACT

Many plant extracts could be considered as natural effective tool against yellow mite instead of synthetic chemicals. The research was aimed at studying the effects of plant extracts on *Polyphagotarsonemus latus* Banks infestation and jute yield production. This experiment was conducted in Manikganj, Bangladesh following randomized complete block design with three replications. Treatments were Neem oil 3% (T_1), Neem leaf extract @ 1:30 (T_2), Mahagoni seed extract @ 1: 10 (T_3) Turmeric powder extract @ 1: 40 (T_4), Garlic paste extract @ 1:30 (T_5) and control (T_6). Percent reduction of mite population was found in neem oil (87.94%), neem leaf extract (85.76%) and garlic paste extract (86.48%) at 72 hrs after spray. After 7 days of spraying, Neem oil treated plot received the best reduction (89.05 %) followed by neem leaf extract (87.03%), Mahogany (79.60%), turmeric (78.02%), and garlic (80.06%), respectively. Neem oil treated plot showed highest fibre yield (2.95tha^{-1}). Control plot showed highest mite infestation with lowest yield contributing attributes. Neem oil/leaf extract and mahogany seed extracts were found effective to control yellow mite infestation resulting higher fibre yield production.

KEYWORDS

Plant extracts, *Polyphagotarsonemus latus*, *corchorus olitorius*.

1. INTRODUCTION

Jute is a vital sustainable natural fibre crop next to cotton (Das *et al*., 2014). It is a prime fibre crop in the world. It positions second to the cotton among all the natural fibre manufacture (Talukder *et al*., 1989). About 90% of the world's jute is produced in India and Bangladesh (Atwal and Dhaliwal, 2007). It is the most important cash crop and the chief foreign exchange recipient of Bangladesh. Bangladesh became the second largest producer of jute in the world with annual production estimated at 68.19 lakh metric tons in 6.66 lakh hectare lands in FY 2019-20 which covers 42% of the total jute production of the world. Raw Jute export earnings are US$ 130 million in FY 2019-2020 covering 0.39% of total export. At the same time, jute goods scored US$ 752 million in FY 2019-2020 covering 2.23% of total export (BER, 2020). Jute is attacked by about 40 species of insects and mites at all stages of the growth from seedling to harvest (Kabir,1975). Among them yellow mite, *Polyphagotarsonemus latus* (Banks) is one of the most common and a serious pest of jute. It sucks cell sap from young apical leaves causing in wrinkle and curly appearance of tender leaves. About 38% of fiber yield of jute is reduced due its attack under field condition. Yellow mite, *Polyphagotarsonemus latus* Banks is one of the major destructive pests of jute (Rahman and Khan, 2006) and the loss caused by *P. latus* is reported to the extent of 10.00 - 42.00% depending on the level of infestation (Pandit et al., 2002). Both yield and quality of fibre are reduced due to the attack of this pest (Kamruzzaman *et. al*., 2013). Mite attacks the softer portions of the jute plants (Hath, 2000). It is very small and quite impossible to see without a 10X or stronger hand lens (Pena and Campbell, 2005). The mite's toxic saliva causes twisted, hardened and distorted growth in the terminal bud of the plant (Baker, 1997). The blooms abort and plant growth is stunted when large populations are present (Denmark, 1980; Wilkerson *et al*., 2005).

Generally, chemical acaricides are used to control mite pest of jute. The indiscriminate use of synthetic chemicals for the control of mite pests creates several problems in agro-ecosystem such as direct toxicity to beneficial insects, fishes and human (Goodland *et al*., 1985; Pimentel, 1980 and Munakata, 1977) gain resistance to chemicals (Schmutterer *et al*., 1983; Waiss and Chen, 1981) out breaks of secondary pests (Hagen and Franz, 1973). health hazards (Bhaduri et al., 1989), environmental pollution (Fishwick, 1988, Kavadia *et al*., 1986) susceptibility of crop plants to insect pests (Pimentel, 1977) and increases environmental and social cost (Pimentel *et al.,* 1981). Pesticidal control of mite is very expensive and unselective and recurrent use of pesticides causing several hazards (Goodland *et al.,* 1985; Devi *et al.,* 1986; Fishwick, 1988; Bhaduri *et al.,* 1989). The application of pesticide revises pest and predator/parasitoid ratio in the agro ecosystem imposing more harm rather than worthy. In general, control of pests by applying different chemical pesticides is very health risky, expensive and threat to their parasite, predators and create imbalance in environment. Therefore, today's scientists are trying their level best to find out suitable eco-friendly pest control measures. Alternative or biodegradable substitutes are now intensely sensed in many developed countries to minimize the loss of synthetic chemicals in mite control. The naturally active natural plant extracts can play a significant role in this regard. These plant products may help to keep the drawbacks of conventional methods within bounds.

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Different botanical insecticides like pyrethroids, rotenoids, nicotiniods and unsaturated isobutyl amides have been studied extensively and documented information relating to structure-activity relationships of these compounds (Crosby, 1971). More than 2000 plant species from different families and genera have been described to contain toxic compounds and a multitude of chemical compounds holding diverse and novel types of structural patterns being isolated from various plants (Adityachaudhury *et al*., 1985). Recently, the derivatives of neem (*Azadirachta indica)* have become the most promising source of natural insecticides to world scientists (Saxena, 1989). It has been reported that neem has repellent, toxicant, antifeedent, insect growth inhibitors, chemo-sterillant and anti oviposition activities (Gujar, 1992). Oils and/or vapors in garlic are directly toxic to insects suggested by some studies (Park and Shin 2005, Zhao *et al*., 2013). Upadhyay and Singh (2012) believe that the lectins or lectin like compounds (ASAL) in garlic may interfere with different aspects of the insect life cycle. Lectins serve as plant defences against insects, viruses, fungi, bacteria and mites (Peumans and Van Damme 1995, Saha *et al*. 2007, Roy *et al*., 2008, Chakraborti *et al*. 2009). These garlic compounds are toxic to many insects and can be a strong deterrent to feeding and egg laying behavior (Michiels *et al*., 2010). Some plant product acts as antifeedant, some as repellant, some as insecticides, homicidal and growth inhibiting factor against many species of insect pest (Soudarajan *et al*., 2012). The fresh juice, alcoholic and aqueous extracts, and essential oils of *Curcuma longa L.* have demonstrated insecticidal effects against a number of insect pests, and also repelled mosquitoes (Tavares, W. S. *et al.,* 2013; Iqbal, J. *et al*., 2010; Sukari, M. A. *et al*., 2010; Damalas, C. A. 2011). Natural products from this turmeric plant also have analgesic, antibacterial, antifungal, anti-inflammatory, antioxidant, and digestive properties (Chattopadhyay, I. *et al*., 2004; Ali, B. H. *et al*., 2006).

In Bangladesh, a very few studies have been piloted on the efficacy of plant extracts against yellow mite infestation. In view of the above mentioned facts and insufficiency of linked knowledge on the performance of natural plant products, this study was investigated with the objective to assess the comparative efficacy of different plant extracts against yellow mite and its impact on yield contributing attributes of jute.

2. Materials and Methods

Pesticidal efficacy of selected plant extracts on yellow mite, *Polyphagotarsonemus latus* (Banks) experiment was led during April-August 2019 in the experimental field of Jute Agriculture Experimental Station (JAES), Manikgonj, Bangladesh following randomized complete block design (RCBD) with three replications. Treatments were Neem oil 3% (T_1), Neem leaf extract @ 1:30 (T_2), Mahagoni seed extract @ 1: 10 (T_3) Turmeric powder extract @ 1: 40 (T_4), Garlic paste extract @ 1:30 (T_5) and control (T_6). The plot size was 2×2.1 m^2 having 1 m space between the plots and 30 cm between the lines. Germination test of *Corchorus olitorius* jute variety O- 9897 was done before sowing at entomology laboratory in the main field. Above 80% germinated seeds of *Corchorus olitorius* jute variety-09897 were sown into the experimental field on April 2019 in 18 plots. Normal agronomic practices like weeding, thinning, irrigation etc. were done as per recommendation. Manures and fertilizers were applied as per recommendation of Agronomy division of BJRI. For the preparation of neem leaf extract, green leaves were collected from the neem tree and then dried for 7 days. Dry neem leaves of 10 g were soaked in 300 ml water for overnight and the extracts were filtered through fine lilen cloth to get 1:30 neem leaf extract. The dried turmeric was grinded with the help of an electric blender and 10 g turmeric powder was soaked in 400 ml water for overnight to make 1:40 turmeric powder extract. Garlic was collected from the local market, sun dried and then crushed with the help of an electric blender. 300 ml water was dissolved into 10 gm garlic paste and kept for overnight to make 1:30 of garlic paste extract. Mahogany seeds were collected from mahogany plants and then sun dried and crushed by an electric blender.10 g mahagoni seed paste was dissolved in 100 ml water and then kept for overnight to make 1: 10 mahagoni seed extract. Neem oil used in this experiment was collected from local market, Dhaka and its concentration was 100%. From this stock, 3% neem oil solution was prepared by adding 97 parts of distilled water with 3 parts neem oil. The emulsion of neem oil in water was prepared by adding 1% liquid nikalin detergent (emulsifier) as described by Mariappan and Saxena (1983). Two times of spraying was done. The first spraying was done at 50 DAS and the second was done at 65 DAS. Spraying was done with the help of a hand-operated sprayer in the afternoon giving attention to avoid sunlight and drift caused by strong wind. The number of yellow mite/cm^2 leaf was counted with the help of sterio-microscope before spray and 24 hrs, 48 hrs and 72 hrs after spray.The number of mite infested plants was counted before spray and at 3 and 7 days after spray. Five plant of each plot was selected randomly to count plant height, base diametet and fibre yield. At 120 days after sowing, plant height and base diameter were determined. Plant height was measured with a meter scale from the ground level to the top of the plants and expressed in meter. Base diameter was measured with a slide callipers scale from the base of the plants and expressed in centimeter. After harvest, the total yield was calculated in ton per hectare. Percent reduction of mite infestation per plot and per cm^2 leaf area, percent increase of height, diameter and yield over control was estimated. Percent reduction/ percent reduction over control of yellow mite was recorded using the following formula-

$$(\%)\ \text{Reduction} = \frac{A-B}{A} \times 100 \text{ ---------- (i)}$$

Here,

A = No. of mite per cm^2 leaf /mite infested plant in control plot

B = No. of mite per cm^2 leaf / mite infested plant in treated plot

Data were analyzed by using Statistix10 software for analysis of variance. Mean values were ranked by LSD at 5% level of significance which was used to compare the mean differences among the treatments (Gomez and Gomez, 1984).

3. Result and Discussion

3.1 Effect of different plant extracts on yellow mite population at different hours after spraying

Effect of different plant extracts showed significant difference on the survival of *P. latus* after 24, 48 and 72 hours of spraying. The mean number of jute yellow mite received lowest (14.27/ cm^2 leaf) survival in the plot treated with Neem oil at 24hrs (Table 1). At 72 hrs after spraying, Neem oil showed lowest (5.22/ cm^2 leaf) population of yellow mite which was statically similar with Garlic paste extract (5.83/ cm^2 leaf) and Neem leaf extract (6.12/ cm^2 leaf) treated plot (Table 1). Other plant extracts showed different performance against *P. latus* survival. Control plot in every case showed highest survival of *P. latus* in jute crops. It clearly indicates that different plant extracts has toxic effect to control yellow mite population. Among them, neem oil showed highest toxic effect on jute yellow mite.

This result is strongly supported by Rahman *et al*., (2016) who stated that neem oil (4.67/ cm^2 leaf) and mahogany (7.33/ cm^2 leaf) oil showed lowest survival of yellow mite after 3 days of spraying. Hossain *et al.,* (2013) reported that green neem leaf extract, dry neem leaf extract, neem oil, Turmeric powder extract and garlic paste extract of same dose had significant influence in reducing the mean number of jute yellow mite giving 6.33, 5.33, 4.00, 6.67, 5.33 and 7.00/cm^2 leaf of jute yellow mite survival after 3 days of spraying. Chari *et al.,* (1999) observed that neem oil at 1% concentration was highly effective in the reduction of yellow mite. Islam *et al*., (2019) and Akter B *et al*., (2019) found the same findings when they tested some plant extracts on jute yellow mite. This result is in agreement with (Singh, 2003) who found that 1 % neem oil was highly effective against survival of jute yellow mite. Anil *et al*., (2001) reported that mahogany and karanja oils of same dose had significant influence in reducing the infestation of jute yellow mite.

Table 1: Effect of different plant extracts on the survival of yellow mite population

Treatments	Mean no. of yellow mite population at different hours			
	Before Spraying	After Spraying		
		24 hrs	48 hrs	72 hrs
Neem oil	63.25a	14.27c	8.49d	5.22d
Neem leaf extract	62.91a	16.87b	10.26c	6.12bcd
Mahogany seed extract	56.26b	18.90b	11.09bc	7.56b
Turmeric powder extract	54.18b	17.24b	12.01b	7.35bc
Garlic paste extract	57.96b	17.96b	11.75bc	5.83cd
Control	54.82b	50.32a	47.16a	43.19a
CV	5.62	7.62	6.81	9.71
LSD (5%)	4.32	2.27	1.51	1.61
SE	2.07	1.09	0.72	0.77

3.1.1 Survival percent of mean no. of yellow mite population

Survival percent of *P. latus* after 24, 48 and 72 hours of spraying showed that there was a significant difference in the effect of different plant

extracts. The population of jute yellow mite received lowest in the plot treated with Neem oil (22.60%) at 24hrs after spraying (Figure 1). Other plant extracts showed various level of yellow mite population. At 48 hours after spraying, lowest mite population was found in neem oil (13.40%). Neem leaf extract, mahogany seed extract, turmeric powder extract and garlic paste extract showed 16.27%, 19.86%, 22.19% and 20.31% respectively. At 72 hours after spraying, Neem oil (8.27%) showed lowest population of yellow mite which was statically similar with neem leaf extract (9.77%) and garlic paste extract (10.06%) treated plot (Figure 1). In every case, the highest population of yellow mite was found in control plot at different hours after spraying.

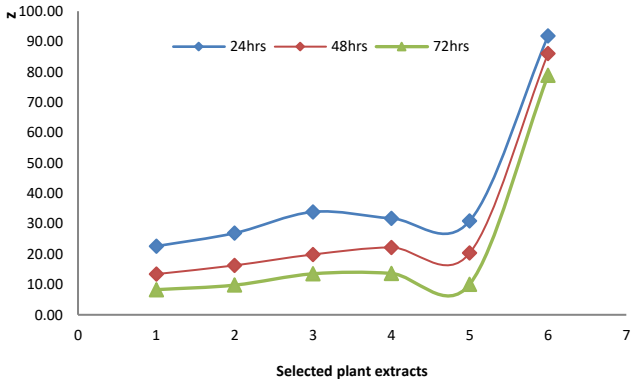

Figure 1: Effect of different plant extracts on the survival (%) of mean no. of yellow mite population

3.1.2 Percent reduction of mite population over control at different hour's interval

The effect of different plant extracts on reduction of yellow mite population was determined at different time intervals after spraying. The highest percent reduction of mite population over control was found in neem oil (71.63%), which was statically different with neem leaf extract (66.49%), mahogany seed extract (62.45%), turmeric powder extract (65.75%) and garlic paste extract (64.29%) after 24 hours of spraying (Table 2). Similarly, after 48 hours of spraying, neem oil showed better performance (81.97%) in percent reduction of mite population over control while the other treatments also significantly reduced mite population over control. After 72 hours of spraying, the highest percent reduction of mite population over control was found in neem oil (87.94%), which was statically similar with neem leaf extract (85.76%) and garlic paste extract (86.48%) and the other treatments had significant effect on mite population reduction over control. Therefore, all the plant extracts showed the significant effect for the control of yellow mite population. Among them, neem oil at 3% concentration had the better performance for controlling mite population at all the three times of spraying (Table 2).

Hossain *et al*., (2013) stated that green neem leaf extract, dry neem leaf extract, neem oil, turmeric powder extract and mahogany powder extract of same dose had significant influence in percent reduction of jute yellow mite population over control giving 62.29%, 64.13%, 64.37%, 64.30% and 52.46% reduction of jute yellow mite after 24 hrs of spraying. They also observed that after 72 hours of spraying, the highest percent reduction of mite population over control was found in neem oil (93.47%). The results are supported by the findings of Isman (1993), who told that 1% neem oil and green neem leaf extracts were very much effective for reducing mite population in jute. Sanguanpong and Schmutterer (1992) revealed that cold pressed neem oil reduced the fecundity of mites on treated plants and the survival of nymph hatched from treated eggs and thus reduced the mite population. Therefore, this finding supported the results obtained in the present study. Chari *et al*., (1999) detected that neem oil at 1% concentration was highly effective in the reduction of yellow mite. Banu *et al*., (2007) reported that green neem leaf extract and dry neem leaf were found to be effective and gave 74.6 and 70.8% mortality at 72 hrs after treatment in greenhouse condition in jute. Islam (2007) reported that Green neem leaf extract @ 1: 20 and Neem seed kernel extracts as very much effective against jute yellow mite. Karuppuchamy and Mohanasundaram (1987) reported that 1% neem leaf extract and 5% neem seed kernel were effective against *Tetranychus neocaledonicus* and *Tetranychus urticae*. Islam *et al*., (2019) and Akter B *et al*., (2019) found the same findings when they tested some plant extracts on jute yellow mite.

Table 2: Effect of different plant extracts on the reduction of yellow mite population over control

Treatments	% reduction of yellow mite population over control after spraying		
	24 hrs	48 hrs	72 hrs
Neem oil	71.63a	81.97a	87.94a
Neem leaf extract	66.49b	78.24b	85.76a
Mahogany seed extract	62.45b	76.42bc	82.45b
Turmeric powder extract	65.75b	74.53c	82.92b
Garlic paste extract	64.29b	75.06c	86.48a
CV	5.69	2.93	2.14
LSD (5%)	5.04	3.04	2.44
SE	2.38	1.43	1.15

3.2 Effect of different plant extracts on yellow mite infested plant at different days after spraying

3.2.1 Survival (%) after treatment application

Significant variation of mite infested plant was noticed in different plant extracts to yellow mite attack. The lowest mite infested plant was found in neem oil (19.20) treated plot having no significant difference with neem seed extract (25.60) and turmeric powder extract (27.80) after 3 days of spraying (Table 3). Plot with untreated showed highest number of mite infested plant (99.60), which was significantly different from that of the other treatments. In case of percent plant infestation, neem oil exhibited the best performance having minimum mite infestation (9.89%), which was statically similar with neem leaf extract (13.06%), mahogany seed extract (14.22%), turmeric powder extract (15.50%) and garlic paste extract (15.34%) after 3 days of spraying. In case of 7 days after spraying with different plant extracts, the minimum number of mite infested plant (10.20) was found in the neem oil treated plot which was statistically identical with neem leaf extract (12.20). Mahogany seed extract (19.20), turmeric powder extract (20.60) and garlic paste extract (18.80) were statistically identical. Control plot received highest (93.80) plant infestation (Table 3). Neem oil received lowest percent (5.17%) plant infestation having statistically similar percent infestation with neem leaf extract (6.26%) and garlic paste extract (9.07%). Control plot was in highest (51.43%) position considering percent plant infestation, which was significantly different from other treatments after 7 days of spraying.

Hossain *et al*., (2013) examined the effect of neem (*azadirachta indica*) and other plant extracts on yellow mite of jute. In their study, they found mite infested plant and percent in neem oil 22.67(11.01%), mahagoni seed extract 24.33 (12.71%), garlic paste extract 28.66 (14.55%), turmeric powder extract 31 (15.10%) and green neem leaf extract 28.67(15.15%), respectively after 3 days of spraying. At 7 days after spraying, they found mite infested plant and percent in neem oil 9 (4.36%), mahagoni seed extract 10.33 (5.40%), garlic paste extract 16.33 (8.29%), turmeric powder extract 19.67 (9.58%) and green neem leaf extract 17(8.95%) respectively. The findings of this study are fully supported by Hossain *et al.,* (2013) and Akter B *et al*., (2019) findings.

Table 3: Effects of plant extracts on survival of mite infestation at days after spraying

Treatments	Before Spray		3 days after spray		7 days after spray	
	No. of mite infested plant	% infestation	No. of mite infested plant	% infestation	No. of mite infested plant	% infestation
Neem oil	93.60a	52.38b	19.20c	9.89b	10.20c	5.17d
Neem leaf extract	84.40ab	56.95ab	25.60bc	13.06b	12.20c	6.26cd
Mahogany seed extract	80.20ab	61.53a	28.80b	14.22b	19.20b	9.21bc
Turmeric powder extract	85.80ab	52.56b	27.80bc	15.50b	20.60b	11.37b
Garlic paste extract	78.80b	62.32a	31.40b	15.34b	18.80b	9.07bcd
Control	82.20ab	55.05ab	99.60a	54.42a	93.80a	51.43a
CV	12.23	11.02	17.68	22.29	10.51	19.65
LSD (5%)	13.58	8.26	4.33	6.00	4.04	4.00
SE	6.51	3.96	9.04	2.88	1.94	1.92

3.2.2 Percent reduction over control

In case of percent reduction of yellow mite infested plant over control, the best results were found by the application of neem oil (80.74%) followed by neem leaf extracts (74.27%) after 3 days of spraying (Figure 2). After 7 days of spraying, Neem oil treated plot received the best efficacy against yellow mite attack and reduced mite infested plants 89.05 % which was statically identical with neem leaf extract (87.03%). Other plant extracts, mahogany, turmeric and garlic showed better performance in reducing yellow mite infestation of jute giving 79.60, 78.02 and 80.06 % respectively (Figure 2). On the other hand, the lowest results (68.43%) and (78.02%) were found in garlic extract and turmeric extract after 3 days and 7 days of application, respectively. Das and Singh (1998) reported the efficacy of neem oil and green neem leaf extracts against yellow mite which supported these findings. The findings of this study are directly supported by Hossain *et al.,* (2013 findings. Islam *et al.,* (2012) indicated that neem oil. nembicidine and neem leaf extract were most etfective against jute yellow mite. It has also been reported that neem products were controlled various insect pests (Pasini *et a1.,* 2003; Naganagouda *et al.,* 1987). Banu *et al.,* (2007) reported that green neem leaf extract and dry neem leaf were found to be effective and gave 67.7 and 72.2% reduction of infestation at 7th day after spray in field condition in jute. Islam *et al.,* (2019) reported that neem seed kernel extract, mahogany seed extract, green neem leaf extract and turmeric powder extract significantly reduced the plant infestation by 70.1%, 68.05%, 61.5% and 61.0%, respectively over control.

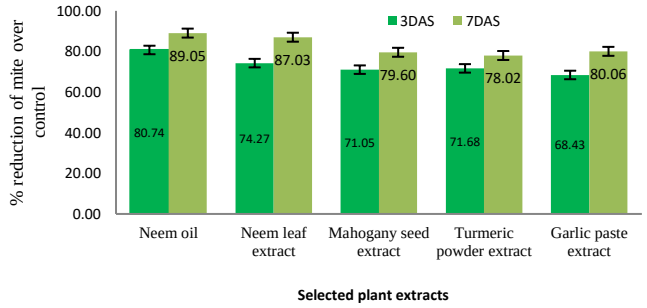

Figure 2: Effect of different plant extracts on the reduction of yellow mite infested Plant over control

3.3 Yield contributing characters

Different plant extracts showed significant variation in influencing yield contributing characters of jute. The highest plant height (3.06 m) was observed in neem oil treated plot which was significantly similar with neem leaf (2.97m) and mahogany extract (2.92m) treated plot. Untreated plot received lowest plant height (2.33m) which was significantly different from other treatments. The highest base diameter (15.18 mm) was found in neem oil, which was significantly similar with neem leaf extract (14.64 mm), mahogany seed extract (14.17 mm) and garlic paste extract (14.26 mm) but significantly different from other treatments (Table 4). In contrast, lowest base diameter (10.48 mm) was found in untreated control, which was meaningfully different from other treatments. Neem oil treated plot showed highest fibre yield (2.95 t ha^{-1}) followed by neem leaf (2.89 t ha^{-1}), mahogany (2.87 t ha^{-1}) and turmeric (2.76 t ha^{-1}). Garlic paste extract gave the fibre yield 2.62 t ha^{-1}, which was statically similar with mahogany and turmeric treatments. The lowest fibre yield (1.87 t ha^{-1}) received in control plot (Table 4). The findings definitely indicated that all the plant extracts have the significant effect on the increase of fibre yield of jute. However, neem oil followed by neem leaf extract and mahagoni seed extract showed the best performance. Neem oil effect on plant height growth as observed in the present study is in conformity with findings reported by Palaniswamy and Ragini (2003) against yellow mite on chilli. They observed that 5% aqueous extract of neem leaf reduced mite population on chilli and increased plant height. These results are supported by the findings of Das and Singh (1998) who reported the highest efficacy of neem oil against jute mite. Neem products effectiveness in the present study was in accordance with the findings observed by Pande *et al.*, (1987). Yeasmin *et al.,* (2013) also found simiilar results after application of Neem oil which increased 24.64% plant height, 27.87% base diameter over control and gave the highest amount of fibre yield (2.68 t ha^{-1}). Hossain *et al.,* (2013) and Rahman *et al.,* (2016) found similar results which are strongly agreed with these findings. Chari *et al.* (1999), who observed that neem oil at 1% concentration was highly effective in increasing the growth of jute through the control of jute yellow mite. Akter B *et al.,* (2019) reported the same results when they evaluated some plant materials against Jute Yellow Mite on *Corchorus Olitorius.*

Table 4: Effect of different plant extracts on yield contributing characters of jute

Treatments	Plant height(m)	Base Diameter(mm)	Fibre Yield (t/ha)
Neem oil	3.06a	15.18a	2.95a
Neem leaf extract	2.97ab	14.64ab	2.89a
Mahogany seed extract	2.92ab	14.17ab	2.87ab
Turmeric powder extract	2.87bc	13.64b	2.76ab
Garlic paste extract	2.70c	14.26ab	2.62b
Control	2.33d	10.48c	1.87c
CV	4.91	6.95	7.52
LSD (5%)	0.18	1.26	0.26
SE	0.09	0.60	0.13

3.3.1 Percent increase of yield contributing characters of jute over control

Percent increase of plant height over control was presented in Table 5. The highest percent increase of plant height over control (31.92%) was observed in neem oil treatment followed by neem (27.86%), mahogany (25.83%) and turmeric (23.96%). On the other hand, the lowest plant height percent increase over control (16.13%) was observed in garlic paste extract, which was significantly different from other treatments. Neem oil treated plot received highest percent increase of base diameter over control (46.48%) and lowest was observed in turmeric powder extract (31.68%). The highest percent increase over control of fibre yield was found in neem oil treated plots followed by neem leaf extract (55.31%), mahogany (554.17%) and turmeric (48.47%) (Table 5). Garlic paste extracts received lowest percent increase over control (40.48%) of fibre yield parameter. These findings are in conformity of the findings of Hossain *et al.* (2013); Akter B *et al.,* (2019) and Islam *et al.,* (2019).

Table 5: Effect of different plant extracts on increase (%) of yield contributing characters of jute over control

Treatments	Plant height(m)	Base Diameter (mm)	Fibre Yield (t/ha)
Neem oil	31.92a	46.48a	58.25a
Neem leaf extract	27.86a	41.53ab	55.31ab
Mahogany seed extract	25.83a	36.72ab	54.17ab
Turmeric powder extract	23.96ab	31.68b	48.47ab
Garlic paste extract	16.13b	37.52ab	40.28b
CV	25.49	23.83	22.64
LSD (5%)	8.59	12.39	15.57
SE	4.05	5.85	7.35

3.4 Principal component analyses

Principal component analysis (PCA) is a statistical tool that permits summarizing the information content in large data tables by means of a smaller set of "summary indices" that can be more easily visualized and analyzed. In the 1st principal component, all the characters received negative values where neem, mahogany and turmeric showed high vector values and the other characters showed low vector values (Table 6). In the 2nd principal component, all the characters except mahogany and turmeric tested positive values where neem oil showed high vector values and the other characters showed low vector values. In 3rd component, all the characters received negative value except neem oil and turmeric where turmeric showed high vector values and the other characters showed low vector values. In 4th component, all other characters received negative except neem leaf where neem leaf showed high vector values. In the last component, turmeric and garlic showed negative values and all other characters received positive values where mahogany and garlic received high vector values and the other characters showed low vector values.

Table 6: Vector components of different plant extracts

Factors	1	2	3	4	5
Neem oil (1)	-0.2303	0.9110	0.0808	-0.1736	0.2834
Neem leaf extract (2)	-0.5028	0.0455	-0.1252	0.8541	0.0038
Mahogany seed extract (3)	-0.4981	-0.3661	-0.2868	-0.3187	0.6588
Turmeric powder extract (4)	-0.4043	-0.1793	0.8891	-0.0978	-0.0656
Garlic paste extract (5)	-0.5316	0.0416	-0.3241	-0.3596	-0.6938

The eigenvalues, variabilities and cumulative variabilities among the principal components in PCA analyses were shown in Table 7 and scree plot analysis (Figure 3). The variabilities increased with increasing the eigenvalues, but the variation in cumulative variability is vice-versa (Figure 3). In this analysis, the first two principal components having Eigenvalues ≥ 1.0, accounting for 63.0% of total variations. The first principal component recorded variations about 60.0%; while the second 19.7%, third 11.4%, fourth 5.3% and fifth 0.6% of the total variations (Table 7).

Table 7: Eigenvalues, percent of variance and Cumulative percent of variance of different plant extracts in PCA (Based on Correlation Matrix)

Eigenfactors	Eigenvalue	Variance (%)	Cumulative variability (%)
Neem oil	3.15093	63.0	63.0
Neem leaf extract	0.98660	19.7	82.8
Mahogany seed extract	0.57001	11.4	94.2
Turmeric powder extract	0.26384	5.3	99.4
Garlic paste extract	0.02861	0.6	100.0

A scree plot displays how much variation each principal component captures from the data. A scree plot is a diagnostic tool to check whether PCA works well on data or not. Principal components are created in order of the amount of variation they cover. PC_1 captures the most variation, PC_2 — the second most, and so on. Each of them contributes some information of the data. In a PCA, there are as many principal components as there are characteristics. Leaving out PCs and lose information. The primary y axis is eigenvalues and secondary y axis is cumulative variability (%). X axis indicates components (factors) (Figure 3). An ideal curve should be steep and then bends at an "elbow". This is called cutting-off point and after that it flattens out. In Figure 7, just PC 1, 2, and 3 are enough to describe the data.

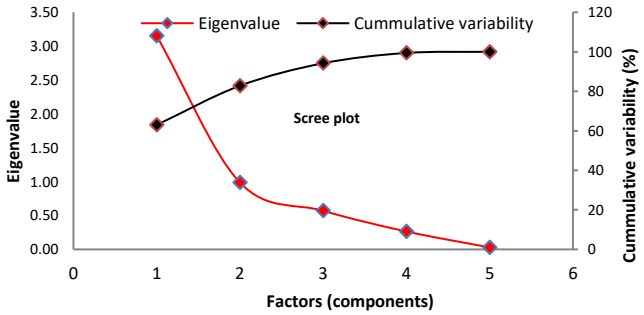

Figure 3: Eigenvalues and cumulative variability (%) in PCA scree plot

3.5 Box and Whisker Plots

A box and whisker plots displays the five-number summary of a set of data. Minimum, first quartile, median, third quartile, and maximum are the five number summaries. A box is drawn from the first quartile to the third quartile. A vertical line goes through the box at the median. The whiskers go from each quartile to the minimum or maximum. The first quartile (Q_1) is the median of the data points to the left of the median. The third quartile (Q_3) is the median of the data points to the right of the median. The minimum and maximum is the smallest and largest data point respectively. The five-number summary divides the data into sections that each contains approximately 25 % of the data in that set. Five plants extracts effect on reduction of yellow mite infestation after spraying are summarized with this plots.

In case of hours after spray data of neem oil, median =82.5, minimum = 69.71, maximum=88.95, Q_1=72.85 and Q_3=87.3. Since Q_1=72.85, it means that about 25% data is lower than 72.85 and 75% data is above than 72.85. Since Q_3=87.3, it means that about 75% data is lower than 87.3 and 25% data is above than 87.3. So, the five number summaries are 69.71(min.), 72.85(Q_1), 82.5 (median), 87.3 (Q_3) and 88.95 (max.) (Fig.3). Similarly, for neem leaf extracts= 65.17 (min.), 66.42(Q_1), 77.33 (median), 85.8 (Q_3) and 88.14 (max.); mahogany = 57.21 (min.), 64.59 (Q_1), 77.63 (median), 81.36 (Q_3) and 85.03 (max.); turmeric= 60.86(min.), 68.45 (Q_1), 74.15 (median), 80.75 (Q_3) and 85.9 (max.) and garlic= 57.65(min.), 67.09(Q_1), 75.36 (median), 86.21 (Q_3) and 87.3 (max.) (Figure 4).

In case of days after spraying data, neem oil = 69.31(min.), 80.84 (Q_1), 86.81 (median), 89.90 (Q_3) and 90.53 (max.); neem leaf extracts= 70.33 (min.), 72.30 (Q_1), 82.96 (median), 87.44 (Q_3) and 88.10 (max.); mahogany = 63.83 (min.), 67.51 (Q_1), 77.21 (median), 81.62 (Q_3) and 85.15 (max.); turmeric= 63.92 (min.), 69.42 (Q_1), 76.04 (median), 78.93 (Q_3) and 83.67 (max.) and garlic= 60.64 (min.), 67.51 (Q_1), 75.38 (median), 81.14 (Q_3) and 84.21 (max.) (Figure 4).

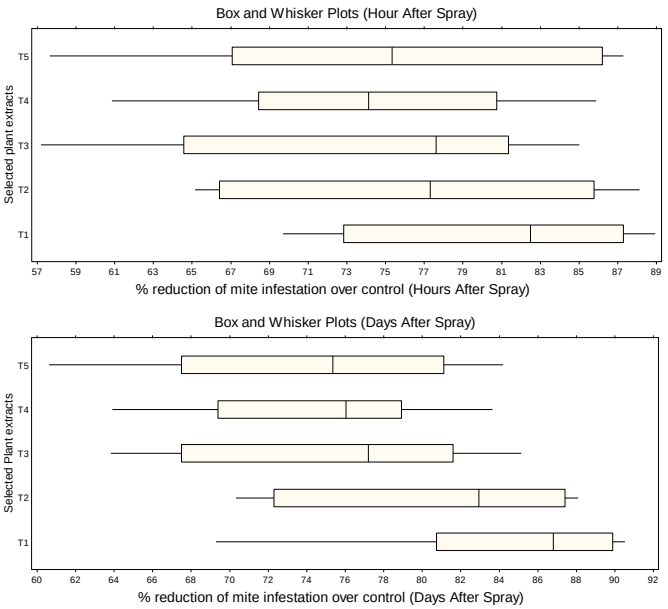

Figure 4: Box and whisker plots of selected plant extracts on reduction of mite infestation

4. Conclusion

The most important issue is pest in crop production because pests can reduce the production of both qualitative and quantitative. Percent reduction of mite population over control was found in neem oil (71.63%), neem leaf extract (66.49%), mahogany seed extract (62.45%), turmeric powder extract (65.75%) and garlic paste extract (64.29%) after 24 hours of spraying. Percent reduction of mite population over control was found in neem oil (89.05%), neem leaf extract (87.03%), mahogany seed extract (79.60%), turmeric powder extract (78.02%) and garlic paste extract (80.06%) after 7 days of spraying. Neem oil treated plot showed highest fibre yield (2.95 t ha^{-1}) followed by neem leaf (2.89 t ha^{-1}), mahogany (2.87 t ha^{-1}), turmeric (2.76 t ha^{-1}) and garlic (2.62 t ha^{-1}).

It is concluded that untreated plot tested highest pest infestation with lowest yield attributes. Neem oil/ neem leaf received lowest mite infestation with higher plant height, base diameter and finally fibre yield followed by mahogany, turmeric and garlic extracts. It is highly recommended to use these plant extracts for controlling most dangerous pest of jute called yellow mite. Further investigation is strongly suggested to explore their toxic effect to yellow mite and other agricultural pests because the use of botanical pesticides is recyclable, comparatively safe for environment, humans and non-target animals.

Conflict of Interest

The author declares that there is no conflict of interest to disclose.

Data Availability Statement

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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