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[1]Department of Botany, Kohat University of Science and Technology (KUST), Kohat, Pakistan
[2]National Institute for Food and Agriculture (NIFA) Peshawar, Pakistan
[3]Department of Microbiology, Abdul Wali Khan University Mardan, Pakistan
[4]Department of Biotechnology and Genetic Engineering, Kohat University of Science and Technology (KUST), Kohat, Pakistan
[5]Department of Botany, Abdul Wali Khan University Mardan, Pakistan

Effects of Neem (*Azadirachta indica*) seed and Turmeric (*Curcuma longa*) rhizome extracts on aphids control, plant growth and yield in okra

Uzair Muhammad[1], Tariq Nawaz Khattak[2], Hazir Rahman[3], M.K. Daud[4], Waheed Murad[5], Azizullah Azizullah[1*]

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Summary

The use of synthetic pesticides to control pests and increase crop yield is a common practice, but they cause several environmental and health problems. Therefore, there is a need to explore alternative approaches to reduce the sole dependence on synthetic pesticides. The present study was conducted to screen the extracts of Neem seed and Turmeric rhizome for pesticidal activities against okra pests (aphids: *Aphis gossypii*). Experiments were conducted in field with four plots. One plot was kept as a control (unsprayed) and one was sprayed with synthetic pesticides, one with Neem seeds extract and one with Turmeric rhizome extract. The effect on number of pests, plant growth and yield was observed at regular intervals. A significant reduction in pests was recorded in all treatments as compared to the control. Neem seed extract was more effective than Turmeric rhizome extract as revealed by 73% decrease in aphids by Neem extract in comparison to 54% by Turmeric extract after last application. Both the extracts were found to be more effective than the synthetic pesticides in controlling okra pests. Both the extracts had stimulatory effects on okra growth and yield. For example, the total yield of plots sprayed with Neem (53.3 kg plot^{-1}) and Turmeric extract (47.7 kg plot^{-1}) was higher than the yield of control plot (33.8 kg plot^{-1}) and plot sprayed with synthetic pesticides (39 kg plot^{-1}). It is concluded that Neem and Turmeric extracts can be used as alternative of synthetic pesticides for controlling pests' attacks in okra.

Key words: Neem, Turmeric, Aphids, Okra, pesticidal properties, growth and yield

Introduction

Food crops are generally attacked by a number of pests like insects, weeds, and other pathogens which cause substantial losses in agriculture. Crop losses due to different factors like diseases, animal pests and weeds range between 20 and 40% of the total yield (Savary et al., 2006). According to some estimations, the total loss (without crop protection practices) due to pests varied from about 50% in wheat to more than 80% in cotton (Dhaliwal et al., 2002). Generally, crops are attacked by more than 10,000 species of insects, 30,000 species of weeds and by a thousand species of nematodes (Dhaliwal et al., 2010). In addition, about 100,000 diseases in plants are caused by fungi and other microorganisms (Dhaliwal et al., 2010).

It has been observed during the last 40 years that despite a continuous increase in pesticide application, pest attacks have not been significantly controlled and crops losses continue (Pimentel, 2007). Approximately 5.2 billion pounds of total pesticides were used worldwide during 2006 and 2007, with 40% herbicides, 17% insecticides and 10% fungicides (Kiely et al., 2004). Only in the U.S, approximately 1.1 billion pounds of pesticides were used during 2006-07, which was 22% of the total pesticides used worldwide (Kiely et al., 2004). Only to some extent, pesticide use has enabled farmers to minimize crop losses caused by pest attacks (Hamill et al., 2004). Despite their useful effect of protecting crops, synthetic pesticides cause hazardous impacts on the surrounding environment by affecting non-target organisms. The use of pesticides kill targeted organism but as well as kill some beneficial organisms also (Gilden et al., 2010). Synthetic pesticides have serious effects on human health and cause various disorders like breast cancer, the suppression of immune system, disorder of nervous system, respiratory disorder and hormonal damages (Benbrook, 2004). Some chemicals of the commercial pesticides have been investigated for the disruption of male reproductive hormones, low sperm count in men and birth defects in babies (Deepa et al., 2011). It has been estimated that about $1.1 billion dollar per year are spent worldwide on public health problems associated with pesticide-related acute poisonings and cancer (Benbrook, 2004). In addition to their adverse effects on animals and humans, pesticides also adversely affect non-target plants. They reduce metabolite synthesis and translocation and inhibit the processes like photosynthesis, respiration and sterol synthesis in non-targeted crops like tomato, maize, pea, grapes, bean and barley (Magné et al., 2006). Pesticides have some direct harmful effect on non-target plant growth such as shoot yellowing, poor root hair development and reduced plant growth (Walley et al., 2006). Pesticides also affect size, number and morphology of fruits and seeds which can lead to reduce yield and low quality (Magné et al., 2006). In comparison, plants derived pesticides or botanical extracts are non-toxic to the user, easily biodegradable and specific in their action and can serve as models for the development of new synthetic analogues with favorable biological and physicochemical properties (Akbar et al., 2010).

Neem (*Azadirachta indica*) is a large tree with semi-straight to straight trunk and spreading branches. It has been widely regarded as a natural source of pesticides and other agrochemicals. Neem was reported to be the most effective among the 2,400 plant species that have shown pesticidal activities (Girish and Shankara, 2008). The extracts of different parts of Neem (leaves, seeds and bark) were found to control a variety of arthropods, nematodes, fungi, viruses, snails and crustacean species (Girish and Shankara, 2008). The extract of its seeds was effective larvicidal and indicated 70-90% mortality against *Culex larvae* (Hashmat et al., 2012). Neem extract was recommended as the most promising pesticide for effective control of tomato fruit worm, *Helicoverpa armigera* (Shah et al., 2013).

Turmeric (*Curcuma longa*) is the rhizomatous perennial plant of the family Zingiberaceae (ginger family). It possesses a variety of bioactive ingredients that act as repellent and insecticidal agents (Damalas, 2011). Rhizomes powder of turmeric showed repellency against different insects of stored products like *Sitophilus granaries, Tribolium castaneum,* and *Rhyzopertha dominica* (Damalas, 2011).

* Corresponding author

Its extract was also effective against rice insect *Sitophilus oryzae* (DAMALAS, 2011). Turmeric powder with ash showed pesticidal activity against different pests of rice (*Oxya nitidula* and *Cnaphalocrocis medinalis*) and eggplant (*Epilachna vigintioctopunctata*) (SANKARI and NARAYANASAMY, 2007). Similarly, its rhizomes powder was shown to be effective against store-grain pests like lesser grain borer *(Rhyzopertha dominica)* in rice (CHANDER et al., 2003).

Okra (*Abelmoschus esculentus*) is one of the hot summer and annual vegetable grown in plain areas of the world. In Pakistan, Okra is cultivated on an area of about 2.21×10^5 hectares (KASHIF et al., 2008). It is attacked by a number of insects which reduces its growth and yield. Some of the major destructive insect pests of okra are aphids (e.g. *Aphis gossypii),* whitefly (e.g. *Bemisia tabaci*), jassid (e.g. *Amrasca devastans*), thrip (e.g. *Thrips tabaci*) and spotted bollworm (e.g. *Helicoverpa armigera*) (AZIZ et al., 2012). Among these insects, aphids are the major pests of okra in Pakistan (GARDINER et al., 2009). Aphid infestation causes heavy losses in different crops. For example, aphids attack causes a reduction of up to 4.57% in wheat yield in Pakistan (KHAN et al., 2012). Aphids damage maize crops and cause up to 60% loss in yield (HAFEEZ and ZIA, 2009). Aphids also act as a vector and transfer several viruses in potato crops and cause yield losses up to 90% depending on cultivar, infestation and environmental conditions (SALJOQI, 2009). According to an estimate, *Aphis gossypii* causes about 20-40% yield losses in cotton crops in Pakistan (ASLAM et al., 2004). Keeping in view the economic importance of okra and losses in its yield due to pest attacks, the present study was conducted to evaluate the extract of Neem seeds and Turmeric rhizome for pesticidal activities against aphids in okra to provide an easy and cost effective way for the control of aphid attack on okra in Pakistan.

Materials and methods

Experimental field

The present experiments were conducted at Nuclear Institute for Food and Agriculture (NIFA) Peshawar, Pakistan. Okra was grown in plots with a size of 88 × 17 feet. The experimental field was consisted of four main plots: one each for the control (no treatment), synthetic pesticides (Cypermethrin and Bifenethrin), Turmeric rhizome extract and Neem seeds extract (Fig. 1). Each plot was further divided into three equal blocks. Each plot was sprayed with the respective solution at specific intervals as shown in Tab. 1. Normal agronomic practices like soil preparation, irrigation and fertilization were done.

Tab. 1: Dates of extracts application and pests observations.

Application of extracts/ pesticides	Application date	Pests observation date
1st	15.05.2014	21.05.2014
2nd	26.05.2014	01.06.2014
3rd	03.06.2014	11.06.2014
4th	16.06.2014	25.06.2014
5th	30.06.2014	06.07.2014
6th	10.07.2014	18.07.2014

Preparation of plant extracts and pesticides solution

Neem seeds and Turmeric rhizome were purchased from Qissakhwani Bazar in Peshawar. Dried seeds of Neem and rhizome of Turmeric were crushed with electronic blender separately. The ob-

Fig. 1: Images of experimental plots. (a) Control plot, (b) pesticides treatment plot (c) Turmeric treatment plot, (d) Neem treatment plot.

tained powder was mixed with petroleum ether at the rate of 125 g per liter following the method of Soxlet. The mixture was stirred by orbital shaker for five days and then was filtered through fine gauze to remove bigger pieces. The extract was then mixed with 5 liters of water to prepare the final solution for application (Aziz et al., 2012). For comparison purpose, two synthetic pesticides, i.e. Cypermethrin and Bifenethrin, were applied in a mixture form by dissolving 10 ml of each pesticide in 5 liters of water.

Application/spray of extracts

The prepared extracts and synthetic pesticides solutions were applied on their respective plots at different time intervals as shown in Tab. 1, while the control plot was left unsprayed. The first spray was applied after the appearance of pests. All solutions were applied on the same day using a knapsack sprayer. The sprayer was rinsed with clean water before using for each solution. A total of six applications were made for each treatment at different times as shown in Tab. 1.

Pest monitoring

For the investigation of extracts effect on pests, the number of pests per plant and percentage of infected plants were determined after each application. A total of 20 plants were randomly selected in each block of every plot. To collect aphids, a piece of paper was laid under one side of plant, shaken the plant gently on the paper and collected the aphids. The average number of aphids per plant was calculated and the percentage of infected plants in each block was determined. A total of six observations were made at specific interval during the course of experiment as shown in Tab. 1.

Determination of plant growth and yield parameters

Determination of shoot length

After sixty days of plant growth, three plants were randomly collected from each block of every plot. The shoot length in centimeter (cm) was measured with a measuring tape. The average shoot length was calculated as follow:

Average shoot length (cm) = Sum of length of all plants/ total number of plants

Determination of leaf area

Three leaves per plant were collected from randomly selected 20 plants in each block of every plot. The leaf area (cm^2) was calculated from the length and width of a leaf.

Determination of fruits number

For the determination of fruit number, three plants were randomly selected in each block of every plot and the number of fruits per plant was calculated as:

Average number of fruits per plant = Sum of total number of fruits / total number of plants

Determination of fruit length

Three fruits per plant were collected from 20 plants in each block of every plot and the fruit length was determined in cm using a measuring tape.

Average fruit length (cm) = Sum of total length of fruits / total number of fruits

Determination of okra yield

For measuring the okra yield, the fruits were plucked after every four to five days and the yield was measured by an electronic balance in kilogram (kg).

Data analysis

Mean and standard deviation of the three replicates for each parameter were calculated using Microsoft Excel. One-way analysis of variance (ANOVA) was applied to measure the significance of differences among different treatments and the control. The difference was considered to be significant if p value was smaller than 0.05 ($p < 0.05$).

Results

Effect of Neem and Turmeric extracts on aphids

Effect on percentage of infected plants

The percentages of infected plants in different plots are shown in Tab. 2. All the applied solutions, i.e., the Neem and Turmeric extracts and the synthetic pesticides significantly protected okra plants from aphid attacks. In the first observation (after first application), there were 53.33%, 81.66% and 70% infected plants in Neem extract, Turmeric extract and pesticides treated plots, respectively, as compared to 90% in the control. In the second observation (after second application) 50%, 78.33% and 70% plants were attacked by aphids in Neem, Turmeric and pesticides treated plots, respectively, as compared to 85% in the control. The reduction in aphids attacks by Turmeric extract was statistically not significant as compared to the control, but the Neem extract caused a significant reduction in aphids attacks as compared to the control and pesticides. After third spray, 45%, 60% and 63.33% plants were infected by aphids in Neem, Turmeric and pesticides treated plots, respectively, where 80% plants in the control were attacked. In this case both Neem and Turmeric extracts significantly controlled aphids attacks in comparison to the control, but the difference was statistically significant only in the case of Neem extract when compared to the plot sprayed with synthetic pesticides. Both the extracts were shown to be more effective with the passage of time as revealed from third spray and observation onward, where both the Neem and Turmeric extracts caused a more prominent and significant reduction in aphids attacks as compared to the control. Although a natural decrease in pest attacks was observed with time as revealed by the number of infected plants in the control plot at different observation, a prominent effect of Neem and Turmeric extracts can be observed in comparison to the control. The extracts, especially Neem extract was found to be more effective even than the synthetic pesticides (Tab. 2).

Tab. 2: Percentage of infected okra plants observed at six different intervals.

	1st	2nd	3rd	4th	5th	6th
Control plot	90±00^a	85±05^a	80±00^a	68.33±2.88^a	60±00^a	60±00^a
Pesticides plot	70±00^b	70±00^b	63.33±2.88^b	63.33±2.88^b	36.66±5.77^b	36.66±5.77^b
Turmeric plot	81.66±5.77^a	78.33±7.63^a	60±00^b	46.66±5.77^b	33.33±5.77^b	33.33±5.77^b
Neem plot	53.33±2.88^c	50±00^c	45±00^c	33.33±7.63^b	23.33±5.77^c	23.33±5.77^c

Values given are mean ± standard deviations of three replicates. Different letters on each two values indicate significant difference from each other.

Effects on number of Aphids per plant

The effect of Neem and Turmeric extracts on number of aphids per plant is shown in Fig. 2. The obtained results indicate that after first two applications, no treatment caused any significant decrease in Aphids density per plant in comparison to the control. However, thereafter both the Neem and Turmeric extracts were shown to cause a decrease in the number of Aphids per plant in comparison to the control as well as pesticides treated plot. For example, after third observation, there were 18.66 and 20.66 (mean values) of aphids per plant in Neem and Turmeric treated plots, as compared to 25.66 and 27.66 in the control and pesticides treated plot, respectively. The same trend continued and both the extracts were observed to decrease the number of aphids per plant in all the remaining observations. Both the extracts were found to show enhanced protection with the passage of time and repeated application. For example, after sixth and last application, there were only 5.66 and 9.66 (mean) aphids per plant in Neem and Turmeric treated plots in comparison to 17 and 21 aphids in pesticides and control plots, respectively. After last application, Neem and Turmeric caused a 73 and 54% reduction in the number of aphids per plant, respectively. It was also observed that both the extracts were more effective than the synthetic pesticides as revealed by the obtained results (Fig. 2). Although after fourth application, the synthetic pesticides significantly controlled aphids in comparison to the control plot but this effect was much smaller than the Neem and Turmeric extracts. A comparison of both the extracts revealed that Neem seeds extract was more effective than the Turmeric rhizome extract as can be seen by a 73% decrease in aphids by Neem extract in comparison to 54% by Turmeric extract after last application. It is noteworthy to mention that like the natural decrease in the percentage of attacked plants, a natural decrease in the number of aphids per plant was observed as is evident from the data of control plot at different intervals (Fig. 2).

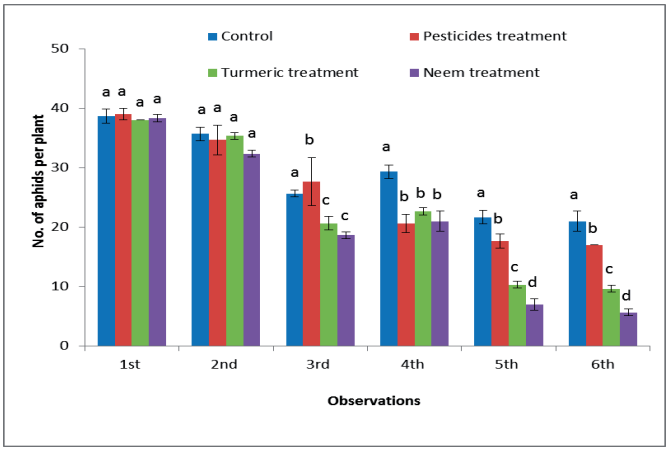

Fig. 2: Number of aphids per okra plant noted at different observations. The chart bars show the mean value of three replicates in each set of experiment while the standard deviation is shown by error bars. Different letters on different chart bars indicate significant difference from each other.

Effects of plant extracts on growth parameters of okra

In order to evaluate whether the application of Neem and Turmeric extracts for pest control will have any adverse effect on plant growth, the effect of both extracts on two growth parameters (shoot length and leaf area) was investigated (Figs. 3 and 4). Both the extracts did not cause any adverse effect on shoot length of okra, but rather caused a slight and non-significant increase in shoot length. Plots sprayed with Neem and Turmeric extracts, the average shoot length was 148.83 and 146.10 cm in comparison to143.90 and 142.20 cm in pesticides treated and control plots, respectively. Both the extracts were shown to cause a slight but statistically significant increase in the leaf area of okra (Fig. 4), and the average leaf area in in plants sprayed with Neem and Turmeric extracts reached 193.26 and 192.66 cm^2 in comparison to 187.66 and 183.9 cm^2 in pesticides treated and control plots, respectively.

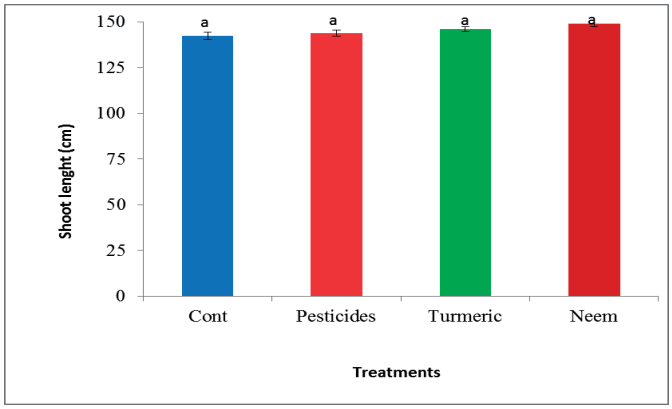

Fig. 3: Shoot length of okra in four experimental plots measured after three months of growth. The chart bars show the mean value of three replicates in each set of experiment while the standard deviation is shown by error bars (Cont. means control plot).

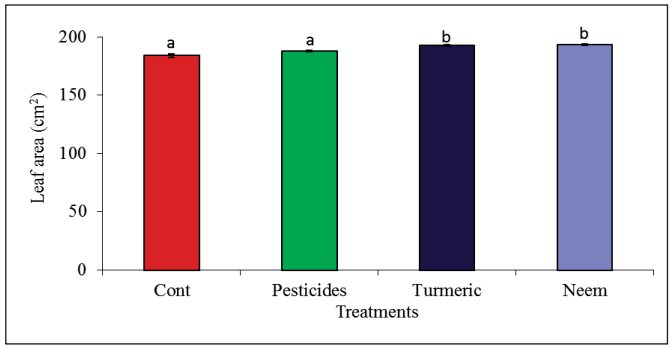

Fig. 4: Area of okra leaf in the four experimental plots measured after three months of growth. The chart bars show the mean value of three replicates in each set of experiment while the standard deviation is shown by error bars. Different letters on different chart bars indicate significant difference from each other (Cont. means control plot).

Effect on yield parameters

Effect on fruit yield

The effect of Neem and Turmeric extracts on fruit yield in term of weight is shown in Fig. 5. All the applied solutions (Neem, Turmeric extracts and synthetic pesticides) significantly protected the okra plants from aphid attacks and resulted in high yield. In first two plucking periods, there was no increase in fruit yield in Neem, Turmeric and pesticides treated plots in comparison to the control. However, thereafter both Neem and Turmeric extracts increased its yield in comparison to the control as well as pesticides treated plots. For example, in third plucking period there were 8.6 kg, 8.5 kg and 8.0 kg fruit yields in Neem, Turmeric and pesticides treated plots, respectively, as compared to 7.0 kg in the control. The same trend continued and both the extracts were observed to increase fruits yield in all the remaining observations. Both the extracts were found to give higher yield with the passage of time and repeated application as compared to the control. For example, in ninth plucking period there

were 5.0 kg and 4.0 kg fruits yield in Neem and Turmeric extracts treated plots as compared to 1.2 kg and 1.8 kg in the control and pesticides treated plots, respectively. In tenth plucking period there were 6.0 kg and 4.5 kg fruits yield in Neem and Turmeric treated plots in comparison to 0.5 kg and 1.2 kg in the control and pesticides treated plots, respectively. It was also shown that both the extracts were more effective than the synthetic pesticides as revealed by the obtained results (Fig. 5). Although after fourth application, synthetic pesticides increased fruits yield in comparison to the control plot but this effect was much smaller than the Neem and Turmeric extracts. A comparison of both the extracts revealed that Neem seeds extract was more effective than the Turmeric rhizome extract as can be seen by 6.0 kg fruits yield by Neem extract in comparison to 4.5 kg by Turmeric extract after last application. The obtained results (Figs. 5 and 6) revealed that a natural decrease in fruits yield was observed with the passage of time as is evident from the data of control plot at different intervals.

The effect of Neem and Turmeric extracts on total fruits yields of okra in term of weight is shown in Fig. 6. The mean data indicated that both the Neem and Turmeric extracts caused an increase in total yield (kg) in comparison to the control and synthetic pesticides treated plots. For example, there were total 53.3 kg and 47.7 kg of fruit in Neem and Turmeric extracts treated plots in comparison to 33.8 kg and 39.0 kg in the control and pesticides treated plots, respectively.

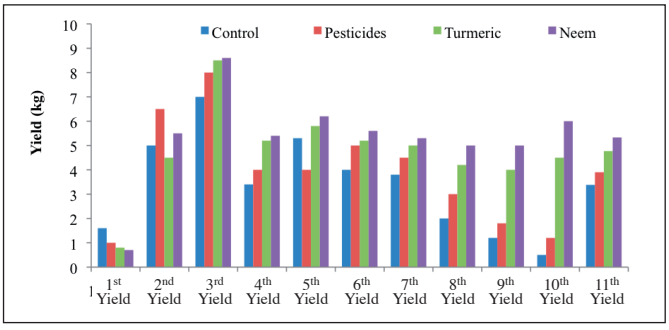

Fig. 5: Yield of okra measured at different intervals.

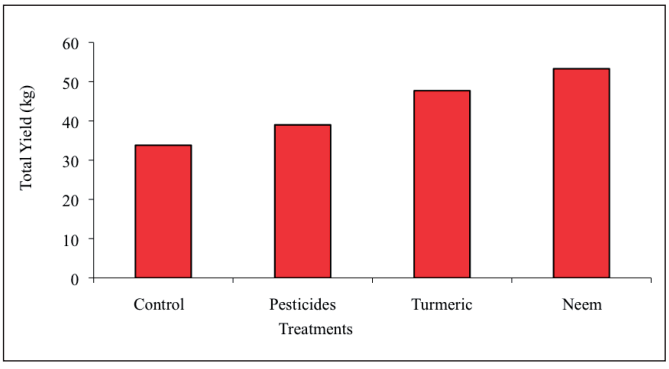

Fig. 6: Total yield of okra (sum of yield of all observations) in four different plots.

Effect on fruit number per plant

The effect of different treatments on fruit number per okra plant is shown in Fig. 7. The obtained results indicate that the extracts of both plants caused a significant increase in fruit number per plant. The average number of fruits on a plant in the control plot was 9.33 which reached 19.66 and 16.66 in plots sprayed with Neem and Turmeric extracts, respectively.

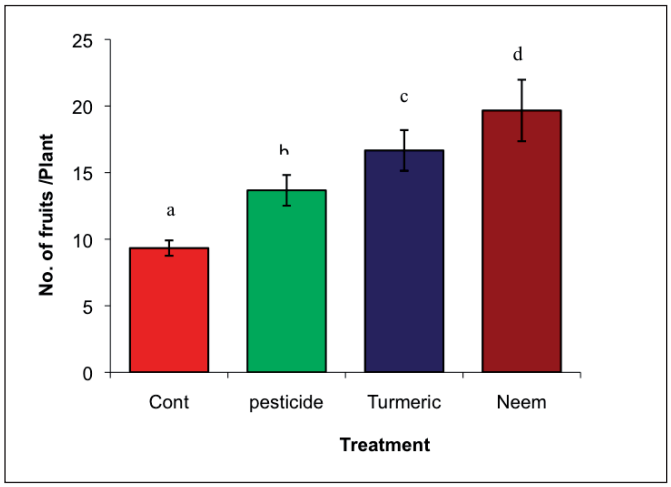

Fig. 7: Number of fruits per okra plant in the four experimental plots. The chart bars show the mean value of three replicates in each set of experiment while the standard deviation is shown by error bars. Different letters on different chart bars indicate significant difference from each other (Cont. means control plot).

Effect on fruit length

The average fruit length of okra in different plots is shown in Fig. 8. There was no prominent effect of any extract on fruit length in okra except a slight but significant increase by the Neem extract.

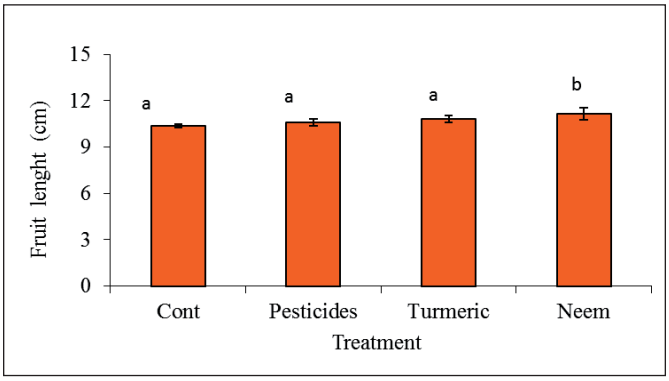

Fig. 8: Average length of fruit in different plots. The chart bars show the mean value of three replicates in each set of experiment while the standard deviation is shown by error bars. Different letters on different bars indicate significant difference from each other (Cont. means control plot).

Discussion

Crop losses due to pest attacks is one of the major global problems. Application of chemical pesticides is the most common and successful methods for pests' control, but synthetic pesticides often have undesirable side effects on the environment such as damaging of non-targeted organisms and accumulation as residue in the environment and food. Therefore, researchers have always been in search of pesticides that are more environmentally friendly and safer from health point of view. This search has led to screening of plants for their pesticidal activities against common pests which has resulted in reporting a number of plant species as promising candidates for use as a source of new plants derived pesticides.

The present study was conducted to screen the extracts of Neem seeds and Turmeric rhizome against aphids in okra, which causes

huge losses of okra every year. It was observed that the extracts of both plants effectively reduced plant infestation by aphid as revealed by the percentage of infected plants and number of aphids per plant. The present observations are comparable to previous reports that extracts of plants like tobacco and Neem effectively reduced the population of bollworm in okra where 11-13% plants were damaged in treated plot as compared to 25-29% in untreated control (SHABOZOI et al., 2011). Similarly, the extracts of Neem, Turmeric, Garlic and Henge significantly reduced jassids population in okra (SOHAIL et al., 2015). Another study reported that the extract of Turmeric caused a noticeable reduction (36%) in the population of insect *Sitophilus oryzae* in rice crop (DAMALAS, 2011). Turmeric rhizomes was found to significantly reduce insects of eggplant (*Epilachna vigintioctopunctata*) and pests of okra including *Amrasca devastans, Anomis flava, Dysdercus cingulatus, Earias vittella, Oxycarenus hyalinipennis, Tetranychus neocaledonicus,* and *Spodoptera litura* (DAMALAS, 2011). Furthermore, the extracts of plants in the present study, particularly of Neem, were found to be more effective than the synthetic pesticides. This observation is supported by a previous report that botanical pesticides, like Neem and Tobacco extracts, had similar or even higher inhibitory effect against pests as compared to the conventional pesticides (SHABOZOI et al., 2011). Another study found that Neem extract showed the highest activity against the insect pest, red flour beetle (caused 68.69% reduction) followed by Sweet flag, Harmal and Turmeric extracts (IQBAL et al., 2010). Similarly, Hossain et al. (2013) reported that Neem extract was more effective than synthetic pesticides like carbamate butocarboxin against pests in Tomato, Onion and Okra. A comparison of the effectiveness of the extracts of the two plants used in this study revealed that Neem seeds extract was more effective than the Turmeric rhizome. It is supported by a previous study of SCHMUTTERER (1990) who found that Neem was the most effective among Neem, Turmeric and Garlic extracts when tested against *Oxycaremus loetus*.

The pesticidal activities of Neem and Turmeric have been attributed to the presence of a number of active compounds in them (Tab. 3). Extracts of these plants might have controlled aphids by acting as repellent, antifeedant and/or as growth and reproductive inhibitors. A previous report suggested that Neem can act as repellent and larvicidal as well as affects egg hatching and reduces fertility in insect pest which results in their progeny inhibition. It can also disturb chemoreceptors of insects and impair their feeding (IQBAL et al., 2006). Turmeric had also been found to possess a variety of bioactive constituents which acts as a repellent and interfere insect behavior and growth (DAMALAS, 2011). According to previous reports extracts of plants like Neem, Turmeric, Harmal and Sweet flag showed repellent effect against red flour beetle in wheat (MATTER et al., 2008). Compounds like Azadirachtin A and B, Salannin and Meliantriol present in Neem have found to protect from insects due to their repellent effects (JAMES et al., 2014). The passage of time and repeated applications of extracts in the present study were found to enhance the effectiveness of extracts. It is similar to a previous reports where Neem extract was found to cause a higher mortality of bollworm in okra as exposure time increased (AHMED, 2000). Similarly, ADESINA and AFOLABI (2014) observed that plant extracts were less effective after initial applications but killed 89% of flea beetles with the passage of time. This enhancement could be due to richness of pesticidal activities of neem seed and turmeric rhizome extracts. The insects continued to feed on the treated plants for some time which caused increase in its efficiency (SCHMUTTERER, 1990).

In order to evaluate whether the application of Neem and turmeric extracts for pest control would have any adverse effect on okra growth and yield, the effect on plant growth and fruit yield was ob-

Tab. 3: Some bioactive compounds from Neem seeds and Turmeric rhizomes.

Neem Compounds	Biopesticidal activities against aphids	References
Azadirachtin A, B Nimbolide Nimbin Sodium nimbidate Mahmoodin Salannin Tetranotriterpenoid (limonoid) Salannol Azadirachtin C, G Salannolacetate Methoxyazadirachtin Vilasinin Nonterpenoidal 2,3-dehydrosalannol	Antifeedancy, Oviposition repellency, reduced in life span, mortality, larval growth inhibition, interruption of aphid reproduction, blocking the development of vector-borne pathogen, growth regulation, fecundity suppression, sterilization	(SU, 1999; IQBAL et al., 2006; JAMES et al., 2014 and LOKANADHAN et al., 2012)
Turmeric Compounds	Biopesticidal activities against aphids	
Curcuminoids Curcumin I Curcumin II Curcumin III Sesquiterpenes Turmerone Demethoxycurcumin Turmeronol A, B Curcumenone Curcumanolide A Tetrahydroxycurcumin Cyclocurcumin Monoterpen Curculonone A, B, C, D	Mortality, adult repellency, changes in biological fitness, fecundity suppression and sterilization, antifeedant, growth-inhibiting effect, fumigant toxicity, reduced oviposition and eggs hatching	(LI et al., 2011; ROY et al., 2015; SIDDIQI et al., 2011 and ABIDA et al., 2009)

served. We found that these extracts had a positive impact on okra growth and yield. OSTERMANN (1992) also found that in Neem seed extract caused an increased growth of okra plants. The higher growth and yield by these extracts can be attributed to the low incidence of pest attacks as revealed by HOSSAIN et al. (2013). The lower growth and yield in the control can be probably due to high occurrence of aphids. Untreated plants possess high numbers of aphids which have caused leaf damages, reduced photosynthesis and consequently reduced growth and yield. The reduction in the number of aphids on okra plants sprayed with plant extracts resulted in superior vegetative growth which in turn produced higher okra fruit yields. Neem extract when applied as pesticide was found to give better yield than conventional pesticides (SATTI and NASR, 2008). Extracts of other plants like garlic and henge were also found to effectively reduce the population of pests in okra and increased its yield (MUDATHIR and BASEDOW, 2004). Similarly, Neem and tobacco extracts increased cotton yield to 1450 kg/ha as compared to the 1000 kg/ha in the control (RAJARAM et al., 2006).

Conclusions

It is concluded that Neem seeds and Turmeric rhizome extracts effectively controlled aphid's attacks on okra and enhanced it growth and yield. Both extracts were found to be more effective than the synthetic pesticides. Based on the present results and previous literature reviewed here, the extracts of Neem seeds and Turmeric rhizome are recommended as effective, ecofriendly, cheap, and easily available remedy for aphids attack in okra.

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Conflict of interest
All authors have participated in this work and all have read and approved the final version of the manuscript. The authors declare no conflict of interest. The paper was a part of M.Phil thesis of Mr. Uzair Muhammad submitted to KUST, Pakistan under the title "Screening of Neem seeds and Turmeric rhizome extracts for biopesticidal activities against aphids in okra".

Authors contributions:
UM and TNK: Conducted experiments
HR, MKD and WM: Data analysis; initial drafting of publication
AA: Designed experiments; overall supervision of experiments; final drafting and correction

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Address of the corresponding author:
Dr. Azizullah, Assistant Professor, Department of Botany, Kohat University of Science and Technology, 26000 Kohat, Pakistan
E-mail: azizswabi@hotmail.com