Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2019; 7(5): 525-531

Received: 07-07-2019
Accepted: 09-08-2019

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Comparative performance and economic efficiency of different pesticides against okra jassids (*Amrasca biguttula biguttula*): Their impact on okra yield and growth attributes

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Abstract

Okra is a vegetable of high economic importance. Among many pests attacking it, jassids are considered to be the major one. Considering the impacts of jassids on yield reduction of okra, health hazards due to chemical pesticides and the high cost of chemical pesticides, a field experiment was conducted in olericulture farm of Agriculture and Forestry University in April, 2019 to assess the comparative performance and economic efficiency of different pesticides against okra jassids; their impact on yield and growth attributes. The pesticides Mugwort green leaves @200g/L, Justicia green leaves @200g/L, Neemix @2ml/L, Nitenpyram @2ml/L and an untreated plot i.e. control was chosen as treatments. Nitenpyram was found to be significantly ($P<0.05$) superior to Neemix, Justicia, Mugwort and control for percent reduction in okra jassids (84-93%) after 48 hours of spray. Both Nitenpyram and Neemix treated plot were statistically ($p<0.05$) similar for yields (26 mT/ha and 22.4 mt/ha respectively). Nitenpyram was superiorly significant ($p<0.05$) for okra plant height, biomass and fruit length from rest of the treatments. The correlation between the percent reduction of pests and yield of okra was found to be 0.733, 0.789, 0.859 and 0.74 (all at $p<0.01$) for the 4 sprays. The benefit cost ratio was highest for plot treated with Justicia (1.78) followed by Neemix, Nitenpyram, mugwort and control. Thus, it would be better to suggest the okra growing farmers of Chitwan to use Nitenpyram for maximum reduction of jassids but for yield purpose Neemix can be suggested for a better yield without using chemical pesticide. Justicia and Neemix both would prove to be economically efficient owing to their high BC ratio (1.78 and 1.65).

Keywords: Botanical pesticide, Okra jassids, BCR, correlation, Mugwort

1. Introduction

Okra (*Abelmoschus esculentus*), also known as lady's finger or bhindi, is a member of the Malvaceae family which probably originated in Ethiopia [1]. It is cultivated in tropical as well as sub-tropical regions of the world due to its high economic importance [2] and [3]. It is widely grown from tropics to sub-tropics and warmer parts of temperate zones in Nepal with total production of 113,676 mT (2016/17) [4]. It is a vegetable crop of utter importance with a varied assemblage of dietetic quality and pronounced health benefits. It is also referred to as " a perfect villager's vegetable " for its sturdy character, nutritive fiber and marked seed protein balance of amino acids (tryptophan and lysine). It is a source of rich nutrients accompanied by numerous health benefits including its beneficial effects against diseases like heart diseases, type 2 Diabetes, gastroenteritis and even cancers [5]. Although it bears such huge benefits, the production of okra is affected by a diverse number of pests and among them, jassids are considered to be the most serious pest.

Okra is very susceptible to insect pests from its initial stages and approximately a total of 72 insect species have been reported to attack it [6]. Among these insects, jassids are infamous for their attack on many agricultural crops including okra. Both immature and adult stages cause havoc in field by feeding on under sides of leaves and sucking saps from the leaves. The survival and feeding of the nymphs of jassids are totally dependent on okra crop [7] and hence cause damage to the growing seedlings as well as hinder fruit set which later cause massive yield reduction upto 50-63.41% [8]. Moreover, this insect declined plant height by 49.8% and leaf size by 45.1% after feeding [9].

The other symptoms include infected leaves curling upward from edges and dead brown spots appear with a pale halo at edges of the leaves. If there is a severe attack, the leaves get dehydrated and ultimately fall [10] affecting growth and bringing reduction in number of fruits, their taste, size and ultimately yield. During feeding, *A. biguttula* injects a toxic material that seriously damages the leaves, which brings burnt like symptoms in the leaves and finally they drop [11, 12].

Control of jassids can be done by various methods like biological control, manual control, cultural control etc. However, chemical method of control is the most effective one that brings rapid control of the pest [13]. In case of okra, neonicotinoids are most effective chemical pesticides for management of jassids [14]. Due to frequent harvesting of the fruits, use of conventional insecticides are not recommended but there is upsurge of pesticide use in the developing countries and particularly the Hindu-Kush Himalayan region [15] including Nepal [16]. When it comes to vegetable crops like okra, there always prevails a time lag between the application of pesticides and harvesting and in an experiment among 1180 vegetable samples, okra was found to have higher level of pesticide residue above Maximum Residual Limit (MR) [17]. Also, the exorbitant cost of synthetic pesticides and the environmental pollutions resulting from the continuous use of chemicals has raised interest for the use of botanicals for crop protection [18]. For the protection of crops, the use of botanical pesticides is practically sustainable as they are easily biodegradable [19]. They help to maintain biological diversity of predators [20] thereby reducing the potential environmental pollution and human health hazards.

Considering the impacts of okra jassids on yield reduction of okra and impact of chemical pesticides on human health, the current research was proposed to use different botanical pesticides for control of okra jassids and to see possible replacement of the chemical pesticides under field conditions. The experiment was also proposed to determine the BC (Benefit Cost) ratio of treatments for determination of the most economical treatment along with determination of impact of these pesticides on okra yield and growth attributes.

2. Materials and methods

The field experiment was carried out in 2019 at Olericulture farm, Agriculture and Forestry University (AFU), Rampur, Chitwan. A well decomposed farm yard manure @ 20T/ha [21] was applied and the field was ploughed. Individual plots were fertilized @ 200:180:60 kg NPK per ha [21]. Nitrogen was supplied through urea, phosphorous through Diammonium Phosphate (DAP) and potassium through muriate of potash (MOP). Half dose of Urea, full DAP and half dose of MOP were applied basally during sowing. The other half of MOP and Urea were applied as three splits (via top dressing) i.e. at 25 days of sowing, during flowering and at fruiting stage respectively [22]. Okra variety Arka Anamika was grown in plots of size 2x1.8 m at 50 x 30 cm spacing in a Randomized Block Design (RBD) with four replications. Sowing was done in April 4, 2019. Seeds were covered with loose soil. The plants were thinned after one month of germination. All the agronomical practices recommended were carried throughout the cropping season.

2.1 Preparation of the pesticidal plant materials

The pesticidal plants, their parts used, chemical pesticide used and their dosages have been presented in Table 1. The fresh leaves of each plant species were collected one day before their application and were crushed with the help of an iron mortar and pestle, and then soaked with the required amount of water in plastic bucket for about 18 hrs., the next day the plant materials were stirred thoroughly in the buckets and then filtered with a fine muslin cloth. Teepol, a sticker, was then mixed to each of the final pesticidal preparations (including Nitenpyram) @ 1ml/L and Neemix @1ml/L.

Table 1: Treatments and their dosages used in the experiment.

Treatments				Dosage
English name	**Botanical name**	**Nepali name**	**Part Used**	
Mugwort plant	*Artemesia vulgaris*	Titepati	Leaves	200g/L
Neemix*	-	-	-	2ml/L
Justicia	*Justicia spp.*	-	Leaves	200g/L
Nitenpyram*	-	-	-	2ml/L
Control	-	-	-	-

*Nitenpyram is a systemic insecticide and Neemix is a neem-based insecticide.

2.2 Application of the treatments

All the pesticidal materials were applied on okra plant with a knapsack sprayer. Maximum care was taken to cover the whole plant surface with the spray materials. The materials were applied in the late afternoon for avoiding the bright sunlight on the spray materials over the plant surface. First spraying was done at about 35 days after planting of okra when 2-3 nymphs of the jassids were seen on each okra leaf. Sprayings were done at weekly intervals and in total 4 applications were made.

2.3 Evaluation of efficacies of the treatments

The efficacies of the treatment were judged as follows:

2.3.1 Effect on insects

2.3.1.1 Okra jassids

5 plants from each plot of each treatment were selected at random for counting the number of jassids; then from each plant 3 leaves (one lower, one middle and one top) were selected and the number of jassids (both adults and nymphs) present on them were counted but the leaves were not removed from the plants. The counts were taken 24 hours before and 48 hours after each spray. The percent reduction of pest population for each treatment was calculated by the formula similar to that used by Alam, Mala, Islam, & Jahan, 2010.

% Reduction = $(Pr - P_o)/Pr \times 100$ (Where, Pr = Pre count plant^{-1} and P_o = Post count plant^{-1})

2.3.2 Effect on plant growth and yield

The effect of various treatments in the plant growth and yield were assessed as follows:

a. **Plant height:** The height per plant was worked out by measuring 5 sample plants from ground level at the time of harvest.
b. **Fruit weight:** Multiple harvesting of the fruits was done and the average fruit weight from 5 sample plants were taken separately for each treatment.
c. **Fruit size:** During each harvest, 10 pods per plot were taken (2 from each of the 5 sample plants) from each treatment, and their length were measured.
d. **Biomass of plant:** After the final harvest, the plants were cut from the bottom and the biomass of the 5 sample plants were taken from each plot.

2.3.3 Correlation between percent reduction of pest and yield

The percent reduction of pests after application of each treatments were calculated and after the final yield was taken for each treatment, the correlation between percent reduction of pest and yield of okra was assessed using SPSS Version 25.0.

2.3.4 Computation of Benefit Cost Ratio (BCR) and Yield

The total yield of okra crop per hectare was calculated by multiplying the yield of okra per plant in different treatments with the total number of plants per hectare. Due to fluctuation in prices throughout the season, the average price per kilogram of the produce was fixed at Rs.40.00 per kg for the calculation of BCR. Total income per hectare was calculated by multiplying the total yield of okra crop with per kg price. For calculating crop protection expenses, the recommended doses of treatments per hectare were recorded and cost per spray was worked out. The total crop protection expenses were calculated by multiplying per spray expenses with total number of sprays. The Benefit Cost Ratio (BCR) were assessed for each treatment based on the net income (From yield of okra) and costs incurred (like seeds costs, plant protection costs, labor costs, etc.).

BC ratio will be assessed as given by Biswas, 2015: BCR = Net Income/ Management Costs

2.3.5 Statistical analysis

All the data were analyzed statistically following Gen Stat 15.0, only the correlation coefficient being determined by using SPSS Version 25.0. The mean differences among the treatments was adjusted as per test with Duncan's Multiple Range Test (DMRT) and Least Significant Difference (LSD) when necessary.

3. Results and Discussions

3.1 Effects of treatments on okra jassids

The reduction of the jassids population (per leaf basis) after 48 hours of treatment has been presented in Figure 1. and Table 2. Here the efficacy of different treatments for reduction of jassids population after first, second, third and fourth sprayings have been interpreted.

After the first spray (Date I), the treatments differed significantly ($P<0.05$) in reducing the jassids population. Nitenpyram (a systemic insecticide) provided the highest control (84.28%) and was significantly ($P<0.05$) superior to Justicia, Mugwort, Neemix and control. The botanicals, Justicia and Neemix were statistically similar ($P<0.05$) with each other and both were significantly superior ($P<0.05$) to Mugwort. Mugwort on the other hand was superiorly significant from the control. Similar results were obtained in the second (Date II) and third spray (Date III) in which Nitenpyram was significantly superior ($p<0.05$) (showing 87.58% and 92.41% reduction of jassids respectively) over rest of the treatments except that in case of second spray, the treatments Mugwort, Justicia and Neemix were at par with each other. In case of the fourth spray (Date IV) Nitenpyram was significantly ($p<0.05$) superior over rest of the treatments (92.71% reduction of jassids), Neemix and Justicia were at par with each other while mugwort didn’t differ significantly from control and also didn’t differ significantly from Justicia and Neemix.

Similar results were also reported by Asif, Muhammad, Akbar, & Tofique, 2016 where, after 48 hours of first application, Nitenpyram was highly effective with 91.50% reduction of jassids population. The highest control of jassids and good systemic activity by nitenpyram may be due to its high-water solubility which definitely led to a proper translaminar action accompanied by a good translocation [23].

Similarly, Neupane F. P., 2000 also reported that the botanicals; neem leaves extract, neem seed kernel extract, justicia leaves were superior than the untreated check and were at par with each other. The efficacy of botanicals like neem for control of jassids have been reported by Ali, *et al*., 2017 in which the total reduction of jassids were 8 to 56% after 1st spray and 13.90 to 68.73% after 2nd spray which is similar with our experiment and also the impact of neem on jassids have been reported by Asrar, 2013 in which plots treated with *A. indica* extracts showed 32.9% reduction in jassids population. The major component of neem-based insecticides is Azadirachtin [24] which have been found to inhibit the synthesis and release of ecdysis hormones at the physiological level, leading to incomplete molting in juvenile insects. In female insects, an analogous mechanism causes infertility [25] thus decreasing the jassids population.

A reduction of 43% and 51% in okra jassids via Justicia leaves extract was reported by Neupane F. P., 2000 in his experiment which is similar with our results. The estimation of phytoconstituents of leaves, in quantitative basis, of *Justicia gendarussa* shows the presence of alkaloids (1.62±0.081%w/w), flavonoids (2.03±0.105%w/w), triterpenoids (0.199±0.009%w/w), carotenoids (7.88±0. 394%w/w), phenolic compounds (2.21±0.11%w/w), sugar (8.74±0.435%w/w) and starch (5.85±0.292%w/w) [26] and several other bioactive secondary metabolites that may act singly or in a whole. Such properties are responsible for their insecticidal activity and antioxidant properties [27] which might have resulted in reduction of okra jassids population

Nonita Devi, 2003 reported that, in their experiment with different plant extracts as treatments, *Artemesia vulgaris* (Linn.) showed percent a 70.65% reduction of okra jassids which can be seen upto 28-39% in our experiment. Gyawali, *et al*., 2015 reported a percentage mortality of cabbage aphids was best shown by *Nicotiana tabacum* L and *Artemisia vulgaris* L for the control of aphids and the LC_{99} value for Artemisia *vulgaris* L was found to at 20% of treatment and the LC_{50} value was found to be 1.25%. Similarly, Gurusubramanian, Rahaman, Samrah, Roy, & Bora, 2008 reported that the plant possesses an excellent anti-feedant properties (60-78%) which explains the insecticidal action of *A. vulgaris* against sucking insect pests.

Table 2: Effects of treatments on Okra jassids.

Treatments	Okra Jassids				
	Dosage % reduction in pest population				
		Date 1	Date 2	Date 3	Date 4
. Mugwort plant	200g/L	38.86 c	33.26 b	34.32 c	28.18 bc
2. Neemix	2ml/L	48.79 b	38.75 b	49.12 b	33.73 b
3. Justicia	200g/L	53.04 b	42.98 b	44.75 b	35.71 b
4. Nitenpyram	2ml/L	84.28 a	87.58 a	92.41 a	92.71 a
5. Control	-	13.98 d	11.16 c	9.98 d	12.17 c

Means in the column with different letters are significantly different and with same letters are similar (P= 0.05; Duncan's multiple range test).

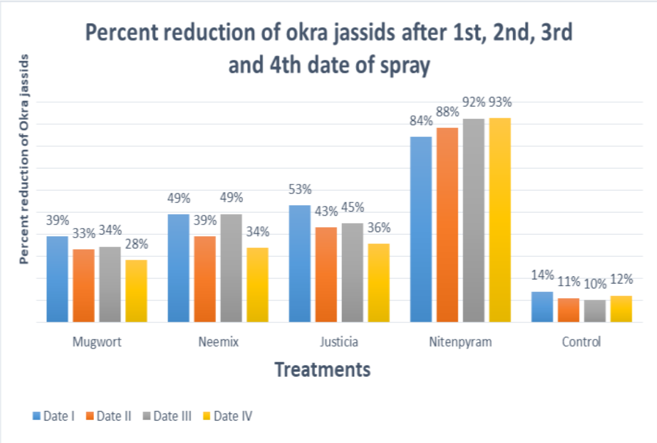

Fig 1: % reduction of okra jassids under different treatments.

3.2 Effects on plant growth and yield

3.2.1 Fruits

3.2.1.1 Fruit weight per plant

The data on fruit weight per plant were significantly (P<0.05) different amidst the treatments (Table 3). Nitenpyram and Neemix were statistically similar (P<0.05) with each other and were significantly (P<0.05) superior to Justicia, Mugwort and control. Justicia and Mugwort were at par with each other and differed significantly (P<0.05) from the untreated check (control). Similar results were reported by Neupane F. P., 2000 where chemical pesticide and a botanical pesticide were at par with each other. Similarly, Patil, Lande, Awasthi, & Barkhade, 2014 also reported the highest fruit weight of okra in case of neonicotinoid treated okra plants.

3.2.1.2 Size of the fruits (fruit length)

Nitenpyram recorded the highest fruit length and was superiorly significant (P<0.05) to Neemix, Justicia, Mugwort and control (Table 3). The botanicals Justicia, Mugwort and Neemix were at par with each other (P<0.05) and were significantly superior (P<0.05) to the control for fruit size. Neupane F. P., 2000 also reported similar results.

3.2.2 Plant

3.2.2.1 Height

Nitenpyram recorded the highest plant height and was significantly (P<0.05) superior to Justicia, Neemix, Mugwort and control as shown in Table 3. Justicia differed significantly from Mugwort and control. Neemix was at par with both Justicia as well as Mugwort, however Mugwort was at par with control and was found to be non-significant. Zhang, *et al*., 2015 reported that plant height was increased by nitenpyram, which may augment the ability of plants to defend against foreign disturbances. Preetha, 2012 reported that okra plants sprayed with a neonicotinoid attained the maximum height which explains the highest plant height in case of Nitenpyram treated plot.

3.2.2.2 Biomass

The plant biomass differed significantly (P<0.05) among the treatments (Table 3). Nitenpyram recorded the highest weight of the plant and differed significantly from rest of the treatments. The treatments Neemix, justicia and mugwort were at par with each other and differed significantly from the untreated check for plant weight. Similar results were reported by Neupane F. P., 2000.

Table 3: Effects of Okra jassids on Okra yield and other plant characteristics.

Treatments	Dosages	Fruits		Plants	
		Weight(g/plant)	Size(Length)(cm)	Height(cm)	Weight(g/plant)
1. Mugwort	200g/L	322 b	15.71 b	115.9 cd	123 b
2. Neemix	2ml/l	404 ab	16.00 b	120.9 bc	112 b
3. Justicia	200g/L	368 b	15.64 b	126.7 b	122 b
4. Nitenpyram	2ml/L	468 a	18.55 a	139.2 a	160 a
5. Control	-	220 c	13.39 c	107.7 d	93 c

Means in the column with different letters are significantly different and with same letters are similar (P= 0.05; Duncan's multiple range test).

3.3 Correlation between the percent reduction of pest and yield

The correlation between the percent reduction of jassids and the yield of okra after first, second third and fourth sprays were found to be highly significant (P<0.01). The Pearson's correlation (R) for first, second, third and fourth sprays were calculated to be 0.733**, 0.789**, 0.859** and 0.74** respectively (Table 4). The coefficient of determination for the first, second, third and fourth spray are 0.54, 0.62, 0.74 and 0.55 respectively which implies that 54%, 62%, 74% and 55% of the total yield of okra were determined by percent reduction of okra jassids in the respective dates. This result shows a positive and strong correlation between the percent reduction of the jassids and the yield of okra. Pedigo, 2002 reported that the protection of crops from pest pressure has frequently been found to result in increased yield which shows the high degree of correlation between percent reduction of jassids and yield. Similar results were recorded by Rahman, 2014 where a co-efficient of determination (R^2 = 0.793), a significant regression co-efficient was seen which showed that the fruit infestation by number of jassids was negatively correlated with the yield (ton/ha) of okra i.e., fruit yield was decreased due to increase of the fruit infestation by number of jassids.

Table 4: Correlation between the percent reduction of the jassids population and yield of okra plant.

		Date III	Date IV	Date II	Date I	Yield of Okra
Date III	Pearson Correlation	1	.862**	.951**	.942**	.859**
	Sig. (2-tailed)		.000	.000	.000	.000
	N	20	20	20	20	20
Date IV	Pearson Correlation	.862**	1	.890**	.870**	.740**
	Sig. (2-tailed)	.000		.000	.000	.000
	N	20	20	20	20	20
Date II	Pearson Correlation	.951**	.890**	1	.941**	.789**
	Sig. (2-tailed)	.000	.000		.000	.000
	N	20	20	20	20	20
Date I	Pearson Correlation	.942**	.870**	.941**	1	.733**
	Sig. (2-tailed)	.000	.000	.000		.000
	N	20	20	20	20	20
Yield of Okra	Pearson Correlation	.859**	.740**	.789**	.733**	1
	Sig. (2-tailed)	.000	.000	.000	.000	
	N	20	20	20	20	20

** The correlate.on is significant at 0.01 level (2-tailed)

3.4 Computation of BCR and Yield

The Benefit Cost Ratio (BCR) analysis of different treatments in suppressing the jassids in the okra crop is shown in Table 5. The results show that yield in Nitenpyram treated plot (26 mt/ha) and Neemix treated plot (22.4 mt/ha) were statistically similar (*p*<0.05) with each other. Nitenpyram differed significantly from other treatments but Neemix showed yields statistically similar to Justicia(20.44mT/ha) and Mugwort (17.89 mT/ha) treated plots. They all were statistically superior to that of control. The BC ratio was found to be highest in Justicia (1.78) followed by Neemix, nitenpyram, mugwort and control respectively. The net income and yield of Nitenpyram treated plot were more than that of other treated plots.

The BC ratio for Justicia treated plot (1.78) was found similar but lower than the results reported by Blankson W., Amoabeng G. M., 2014 where they reported a BC ratio of 29:1 and 25:1 for botanical pesticide treated plot (Siam weed and tobacco respectively) while the plots treated with a chemical pesticide had BC ratio of 18:1 in okra jassids management. Similarly, Shabozoi, Abro, Syed, & Awan, 2011 reported that botanical pesticide treated plot had higher BCR compared to synthetic insecticides and Control. This might possibly be due to the plots treated with extract of Justicia giving significantly higher yields with a relatively higher total income enough to counterbalance the higher cost accompanied with its use.

Table 5: Benefit cost ratio of different treatments against jassids in okra.

Treatments	Yield (mT/ha)	Costs incurred (Rs)	BCR	Net Income (Rs)
Mugwort	17.89 b	4,53,333	1.58	7,15,556
Neemix	22.44 ab	5,45,000	1.65	8,97,778
Justicia	20.44 b	4,60,000	1.78	8,17,778
Nitenpyram	26 a	6,45,000	1.61	10,40,000
Control	12.22 c	4,33,333	1.13	4,88,890

Means in the column with different letters are significantly different (P= 0.05; Duncan's multiple range test).

Price of Nitenpyram = Rs. 300, Price of Neemix = Rs. 180, Cost of okra seeds = Rs. 80, Cost of labor = Rs.200 and costs of herbicides = Rs. 200; costs for Justicia leaves, Neemix leaves have been kept at the locally available rate (Rs. 5 per kg of leaves). (The above costs are the costs involved in total of 72sq. m of the plot which has been converted to 1 ha in the table above. Other variable costs were same in all the treatments.)

4. Conclusion

It can be concluded from the present finding that Nitenpyram was highly significant (*p*<0.05) for jassids population control (86-93%) after 48 hours of spray and Neemix is in par with Nitenpyram for yield. The BC ratio is highest in case of Justicia (1.78) followed by Neemix (1.65), nitenpyram, mugwort and control. It should be advised to the okra growing farmers of Chitwan district to use Nitenpyram for maximum reduction of jassids under high jassids population, better plant height, fruit length and plant biomass. Justicia and Neemix, though not effective as Nitenpyram, could be applied when jassids are few. Neemix can be suggested for a better yield without using chemical pesticide. Justicia and Neemix can be suggested in case the farmers look for a more cost-efficient control owing to their high BC ratio. Therefore, Neemix and Justicia might be used as pesticide for ecofriendly and cost-efficient management of jassids.

5. Acknowledgements

We would like to thank Asst. Professor Rajendra Regmi, Department of Entomology, Agriculture and Forestry University, for his advice and continuous support throughout the research period. Also, we would like to thank CARITAS NEPAL for the opportunity to carryout the field experiment.

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