Research Article

Efficacy of PB Ropes (Synthetic Sex Pheromone) against Pink Bollworm, *Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelichidae), Destructive Cotton Pest, in different Ecological Zones of Punjab, Pakistan

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Abstract | The pink bollworm *Pectinophora gossypiella* (Saunders) have the ability to camouflage themselves with in rosette flowers and bolls and can reduce cotton yield up to 30%. It is considered to be a critically important pest of cotton all over the world. Field trials were conducted in different districts; Vehari, Rajanpur, and Mianwali, of Punjab-Pakistan during 2017 to evaluate efficacy of synthetic sex pheromone [ZZ/ZE-7, 11-Hexadecadiene-1-yl-Acetate] impregnated ropes by using PB rope L dispensers at @ 100/acre, at first pin square stage to cause mating disruption. Performance comparison of control fields compared to PB rope treated fields was assessed throughout cropping period in different ecological zones using Analysis of Variance and Tukey multiple comparison means tests indicated a 95 % reduction in moth trap catches from July to October, in all the tested ecological zones. The percentage flower and boll damage in the control fields was significantly higher than those in the PB ropes fields. There were no significant differences in moth catches, rosette flower percentage or left over boll damage %age among different Tehsils and varieties. However significant differences were observed in boll damages among Tehsils and varieties. Our studies showed significantly lower damage levels in left over bolls at the time of harvest and higher overall cotton yield in PB rope plots compared with control plots.

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Introduction

Cotton has vital role in economy of Pakistan. It is main source of fiber as well as vegetable oil. It is major source of foreign exchange obtained by exporting raw cotton to many countries of world. Cotton production and area is continuously reducing in Pakistan due to biotic and abiotic stresses and competition from other crops.

Among abiotic factors, arthropod pests are considered critically important factors reducing 30-40% yield (Haque, 1991; Kannan *et al.*, 2004). Among arthropod pests, pink bollworm, *Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelichidae) is the most destructive one in all parts of cotton growing world (Ingram, 1994). This single pest can reduce cotton yield up to 30% if not managed properly. Larvae of the pink bollworm feed on cotton squares, blooms and seeds within the growing boll and causes heavy loss to cotton crop. In addition to the destruction of lint and seeds, the quality of the picked lint in heavily infested fields is also lowered. Cotton yield loss could be 10-20% following infestation by pink bollworm (Darling, 1951; Agarwal and Katiyar, 1979). Furthermore, pink bollworm reduces fiber yield up to 17-26% (Luo *et al.*, 1986). Adult preference to viposit on sheltered places, quick entry of larvae into bolls after hatching, internal feeding habits, high reproductive capacity and extensive mobility of its moths seriously challenge control efforts. The control of pink bollworm (PBW) is very difficult with conventional insecticides because they camouflage themselves in rosette flowers and bolls.

Alternate to chemicals regarding pink bollworm management is the use of gossyplure. Gossyplure has been investigated to be naturally occurring sex pheromone of *Pectinophora gossypiella* (Hummel *et al.*, 1973). It is act as specific behavior modifying chemical. The female pink bollworm releases gossyplure to attract male for mating purpose. This scent confuses the males of pink bollworm preventing them from finding and mating with the females. This phenomenon reduces the number of fertile eggs laid which reduces the population of the PBW resulting in less damage to the crop.

Gossyplure has been demonstrated for monitoring purpose of *P. gossypiella* (Bariola *et al.*, 1973; Qureshi *et al.*, 1984; 1993; Buchelos *et al.*, 1999) and is being extensively employed for mating disruption of PBW moths (Kehat *et al.*, 1999; Urquijo and Manzano, 2002). High level of disruption in mating can be obtained by dispersing high doses of gossyplure in cotton foliage. It can reduce damage of the pest in cotton in the long run. PB-ropes provide high rate releases of sex pheromone over a specific period that effectively decrease number of moth caught in traps (Flint *et al.*, 1985; Staten *et al.*, 1987). Mating disruption using PB ropes offers practically an ideal approach for management of pink bollworm in cotton crop (Patil *et al.*, 2004). The objective of present study was to evaluate of efficacy of PB rope L. dispensers against pink bollworm in different ecological zones of Punjab, Pakistan.

Materials and Methods

Field trials were conducted during May to October 2017 in farmers' cotton fields on cotton varieties, N-78, IUB-13, BS-15, Z-33, BT-208, BT-602, BT-142 in Vehari, Burewala, Mailsi, Jampur, Rajanpur, Rojhan and Mianwali, respectively to assess the efficacy of PB rope L. dispensers against pink bollworm. The suitable 50 acre cotton plots were selected randomly preferably sown in mid May 2017 in each zone. PB ropes were installed @ 100 per acre in a block of 50 acre in each zone. The PB rope L. dispensers were tied by twisting the dispenser around stem of the plants at 1st pin square stage i.e. 45 days after sowing. For evaluation of efficacy of PB-ropes five sex pheromone traps i.e. one Trap per 10 acres of cotton field were installed in each 50 acres PB rope block in each zone. The control plots (10 acre) i.e. cotton fields without PB rope were located at least 600m away from the treated fields and sex pheromone traps were also installed in control plots for monitoring. One pheromone trap was installed in each of 10 acres of control block and data of moth catches was collected twice a week for monitoring of pink bollworm moth population. Almost all PB rope treated fields and control were surrounded with cotton crop. The insecticides specific for sucking pests were applied in all fields when sucking pests reached at economic threshold. The selective insecticides (3 sprays) for PBW were applied in control plots in addition to insecticides application for sucking pests. All other agronomic practices were kept almost similar in both PB rope fields and control plots.

The percentage of infested flowers and damaged bolls by pink bollworm larvae were estimated by collecting samples of randomly selected flowers and bolls in both control and treated fields. Observations on moth trap catches were recorded twice a week from July to October in all ecological zones. The observations were tabulated on weekly basis. Trap catches and damage percentages were compared between PB ropes treated fields and control plots. Data were subjected to analysis of variance (ANOVA) and Tukey HSD Multiple Comparisons Mean Test at $P \leq 0.05$ (R-

Language 3.4.3 Core Team, 2017).

Results and Discussion

Population monitoring

Moths catches in traps greatly reduced (F= 368.8, P < 0.001) in PB rope plots compared to control fields in all ecological zones. There were no significant differences in moth catches (F= 2.35, P > 0.01) among different Tehsils and cotton varieties. Mating disruption reached 97.6%, 97%, 96%, 98.9%, 97.7%, 97.8% and 96.5.% in PB rope fields located in Vehari, Burewala, Mailsi, Rajanpur, Rojhan, Jampr and Mianwali, respectively. Overall average moth catches reduction was more than 95% in all zones. Significantly higher moth catches were recorded in control compared to PB rope plots (F= 27.72, P < 0.001) in Mailsi. Whereas, moth catches in different weeks were statistically same (F= 1.08, P > 0.01). Moths trapped in PB rope plots ranged 0.0 to 1.8 compared to 0.0 to 23 moths /trap/week in control. In the control block, trap catches peaked to 23 moths (Figure 1A) per trap per week in 1st week of October and gradually decreased to 9.0 moths per trap per week in last week of October. In the PB rope fields, moth catches initiated in 4th week of September and reached to 1.80 moths per trap per week in 4th week of October.

Moth catches in the PB rope treated fields was found significantly lower compared to control (F = 7.55, P < 0.01) in Burewala. There were no significant differences in moth catches among weeks (F = 1.00, P > 0.01). The number of moths trapped in PB rope blocks ranged from 0.0 to 1.0 compared to 0.0 to 25.50 moths /trap/week in control plots. In the control block trap catches (Figure 1B) peaked to 25.5 moths per trap per week in 1st week of October. Then trap catches gradually decreased to 12 moths per trap per week in last week of October. In the PB rope fields, moth catch started in 1st week of September and reached 0.8 moths per trap per week in 4th week of October.

The number of moth catches in the PB rope treated fields was also found significantly less than that in the respective control (F = 26.56, P < 0.001) in Vehari. Moth catches in different weeks were statistically same (F = 1.11, P > 0.01). In the control, moth catches initiated in July and peaked to 23.00 moths per trap week in 1st week of October (Figure 1C). Then trap catches gradually decreased to 9.00 moths per trap per week in last week of October. In the PB rope fields, moth catches started in 2ndweek of September and reached to 1.8 moths per trap per week in 4th week of October. The number of moths trapped in PB rope block ranged 0.0 to 1.80 compared to 0.0 to 23.00 moths /trap/week in control in Vehari.

The number of moth catches in the PB rope treated fields was found significantly less than that in the respective control (F = 40.72, P < 0.001) in Rajanpur. Moth catches in different weeks were statistically at par (F = 0.99, P > 0.01). The number of moths trapped in PB rope block ranged from 0.0 to 1.0 compared to 1.0 to 22 moths /trap/week. In the control block, moth catch initiated in July and peaked to 22.00 moths per trap per week in 1st week of October (Figure 1D). Then trap catches gradually decreased to 7 moths per trap per week in 4th week of October. In the PB rope fields, started in 1st week of October reached to 0.4 moths per trap per week in 2nd and 3rdweek of October.

Moth catches in PB rope block were significantly lower than that in control (F = 42.43, P < 0.001) whereas, number of moth catches in different weeks statistically equal (F = 1.09, P > 0.01) in Jampur. In the control block, trap catches were less than 15 moths per trap per week during July and August increased gradually to 27.00 moths per trap per week in 1st week of October and then gradually decreased to 8.0 moths per trap per week in 4th week of October (Figure 1E). In the PB rope fields, moth catches started in 2nd week of September and reached to 1.40 during 3rd week of October.

Similarly, significantly lower moth trap catch was observed in PB rope block as compared with control (F = 46.49, P < 0.001) but moth catches in different weeks were statistically same (F = 0.98, P > 0.01) in Rojhan. The number of moths trapped in PB rope block ranged from 0.0 to 1.8 compared to 1.0 to 30.0 moths /trap/week in control. In the control block, trap catches were less than 16 moths per trap per week during July and August (Figure 1F). The moth catches reached to 24.0 and 30.0 in 3rd and 4th week of September, respectively. Then trap catch decline gradually to 6.5 moths per trap per week in 4th week of October. In the PB rope fields, moth catches started in 1st week of October and reached to 1.80 moths per trap per week in 4th week of October.

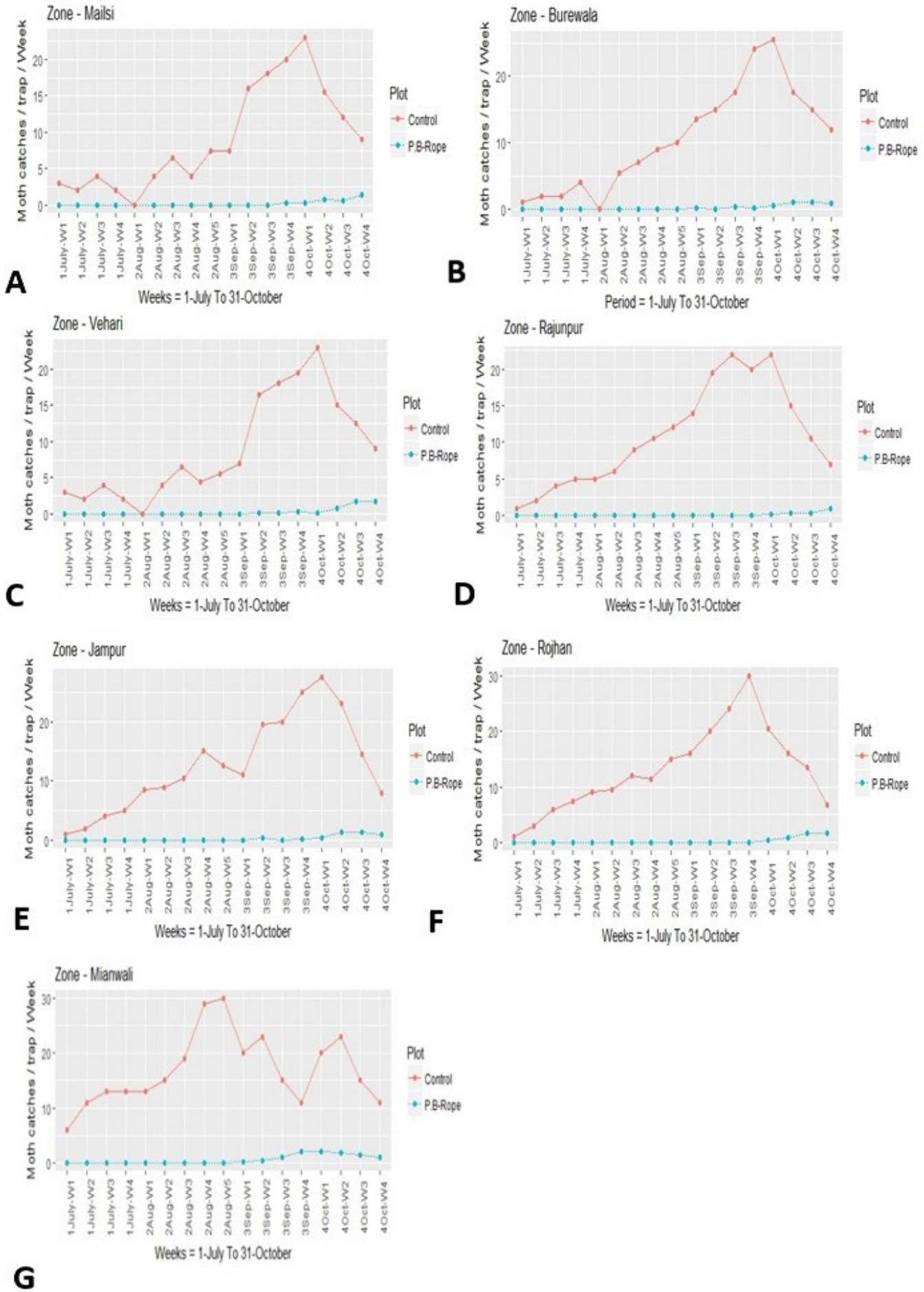


Figure 1 (A-G): *Pink bollworm moth catches in pheromone traps in control plots and PB-rope plots of cotton in Mailsi, Burewala, Vehari, Rajanpur, Jampur, Rojhan and Mianwali.*

The number of moth catches in the PB rope treated fields were found significantly less than that in the respective control ($F = 101.97, P < 0.001$) in Mianwali. Differences in moth catches in different weeks were not significant ($F = 0.99$, $P > 0.01$). The number of moths trapped in PB rope block ranged from 0.0 to 1.8 compared to 6.0 to 30.0 moths /trap/week in control. In the control block, average moth catches per week were less than 13 in July and increased to 30.00 moths per trap per week in 5th week of August (Figure 1G). Then moth catch dropped to 11.00 in last week of October. In the PB rope fields, moth catches started in 1st week of September and reached to 2 moths per trap per week in last week of September and 1st week of October.

Damage estimation

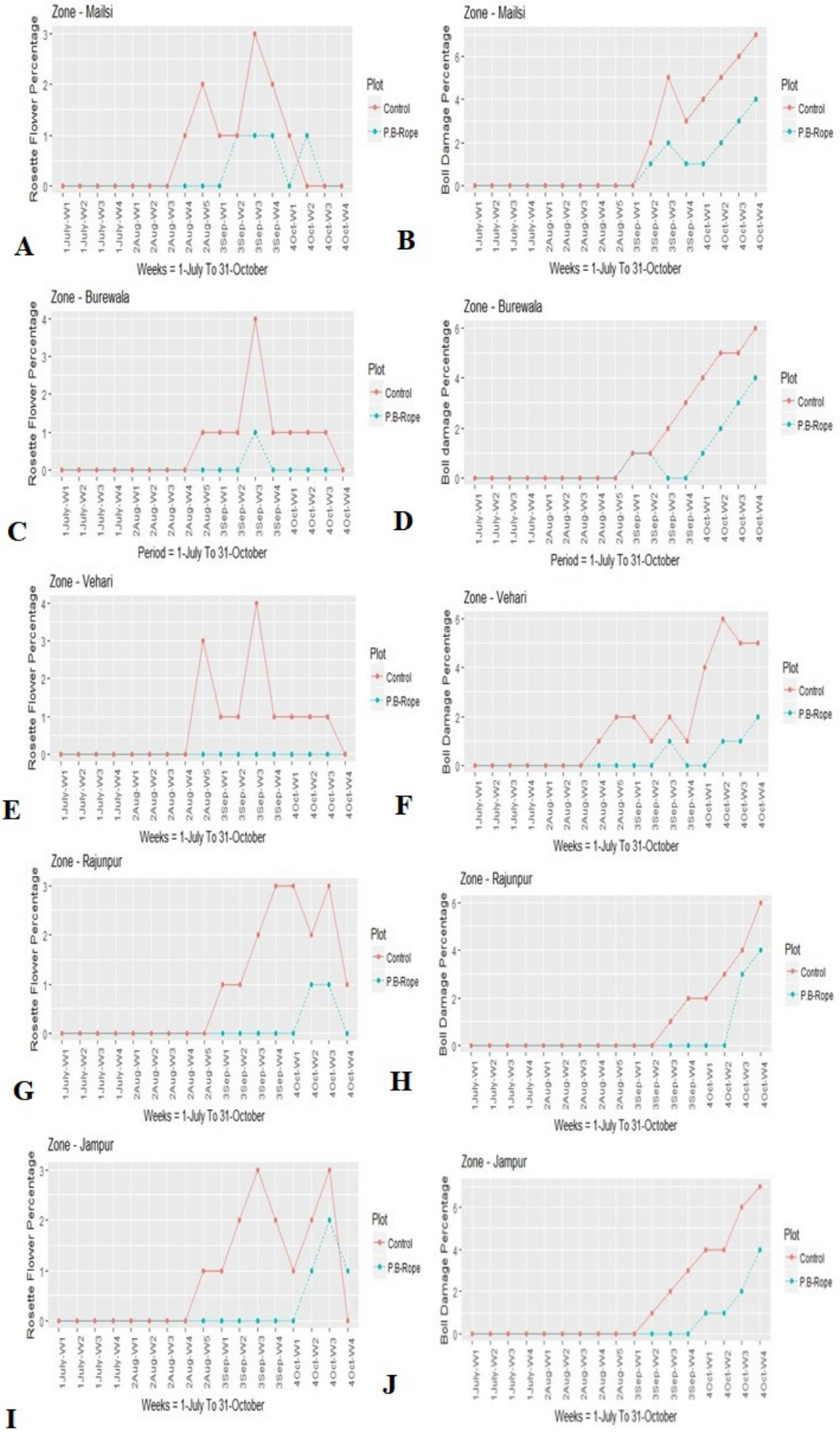
In all ecological zones rosette flower percentage was greatly reduced due to mating disruption. Significant differences were observed in Rosette flower (F = 63.76, P < 0.001) and boll damage percentage between PB rope blocks and control (F = 205.9, P < 0.001) in combined data from all Tehsils. There were no significant differences in Rosette flower (F = 1.4, P > 0.01) among different Tehsils and cotton varieties. However, significant differences were observed in boll damage percentages ($F = 5.4$, $P < 0.01$) among different Tehsils and cotton varieties. It was found flower and boll damage percentages did not proportionally decrease compared to the decrease in trap catches in PB rope blocks.

Significant differences with respect to flowers infestation were observed between the control and PB rope plots ($F = 4.56$, $P < 0.01$) in Mailsi. Flowers infestations in different weeks were statistically same ($F = 2.35$, $P > 0.01$). Pink bollworm made its first appearance in flower during 3rd week of August (Figure 2A) and flower infestation reached to 3% in 3rd week of September in control. It gradually decreased in October. The mean percentage of flower infestation in PB rope block ranged from 0.0 to 1.0 percent compared to 0.0 to 3.0 percent in control. There were significant differences in boll damage in control and PB rope plots ($F = 9.86$, $P < 0.01$) and among weeks ($F = 7.29$, $P < 0.01$) in Mailsi. Bolls damage started in 2nd week of September and reached to maximum in October (Figure 2B) in Mailsi. The mean percentage of boll damage in PB rope block ranged from 0.0 to 4.0 percent compared to control block where boll damage ranged 0.0 to 7.0 percent.

Significant differences with respect to flowers infestation were observed between the control and PB rope blocks in Burwala ($F = 9.30$, $P < 0.01$). Rosette flowers percentage in weeks was statistically same ($F = 2.32$, $P > 0.01$). First rosette flower appeared in 5th week of August (Figure 2C) in Burewala. The mean percentage of flower infestation in PB rope block ranged from 0.0 to 1.0 percent compared to control where rosette flower ranged 0.0 to 4.0 percent. Bolls damage started in 1st week of September (Figure 2D) in Burewala. The percentage boll damage was significantly high in control compared to PB rope plots ($F = 8.22$, $P < 0.01$) in Burewala. Similarly, differences in boll damage among weeks were also highly significant ($F = 6.58$, $P < 0.001$). The boll damage percentage was high in September and peaked in 4th week of October. The mean percentage of boll damage in PB rope block ranged from 0.0 to 4.0 percent compared to control where boll damage ranged 0.0 to 6.0 percent.

Significant differences with respect to rosette flowers were observed between the control and PB rope blocks in Vehari ($F = 7.55$, $P < 0.01$) whereas, flower damage percentages among week were statistically same ($F = 1.10$, $P > 0.01$). Pink bollworm larva appeared in flower for first time in 5th week of August in control plot and rosette flower percentage peaked in 3rd week of September and then decreased. Rosette flower percentage remained 1 percent each in 1st, 2nd and 3rd week of October in control. The mean percentage of flower infestation in control ranged from 0.0 to 4.0 percent compared to PB rope plots where no rosette flower was observed (Figure 2E). Similarly, significant differences in boll damage were observed between the control and PB rope blocks in Vehari ($F = 12.30$, $P < 0.01$). Differences recorded in boll damage in different weeks were not significantly different ($F = 2.31$, $P > 0.01$). Bolls damage started to appear in 4th week of August in control plot of cotton in Vehari (Figure 2F). Boll damage peaked during October. The mean percentage of boll damage in PB rope block ranged from 0.0 to 2.0 percent compared to control where boll damage ranged 0.0 to 6.0 percent.

Significant differences with respect to flowers were observed between the control and PB rope blocks in Rajanpur ($F = 9.99$, $P < 0.01$). Flower infestations in different weeks were statistically same ($F = 1.67$, $P > 0.01$). No rosette flower was observed during July and August in Rajanpur. Flower damage started


Zone - Mailsi
Rosette Flower Percentage
Plot
Control
P.B-Rope
A
Weeks = 1-July To 31-October
Zone - Mailsi
Boll Damage Percentage
Plot
Control
P.B-Rope
B
Weeks = 1-July To 31-October
Zone - Burewala
Rosette Flower Percentage
Plot
Control
P.B-Rope
C
Period = 1-July To 31-October
Zone - Burewala
Boll damage Percentage
Plot
Control
P.B-Rope
D
Period = 1-July To 31-October
Zone - Vehari
Rosette Flower Percentage
Plot
Control
P.B-Rope
E
Weeks = 1-July To 31-October
Zone - Vehari
Boll Damage Percentage
Plot
Control
P.B-Rope
F
Weeks = 1-July To 31-October
Zone - Rajunpur
Rosette Flower Percentage
Plot
Control
P.B-Rope
G
Weeks = 1-July To 31-October
Zone - Rajunpur
Boll Damage Percentage
Plot
Control
P.B-Rope
H
Weeks = 1-July To 31-October
Zone - Jampur
Rosette Flower Percentage
Plot
Control
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Zone - Jampur
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Weeks = 1-July To 31-October

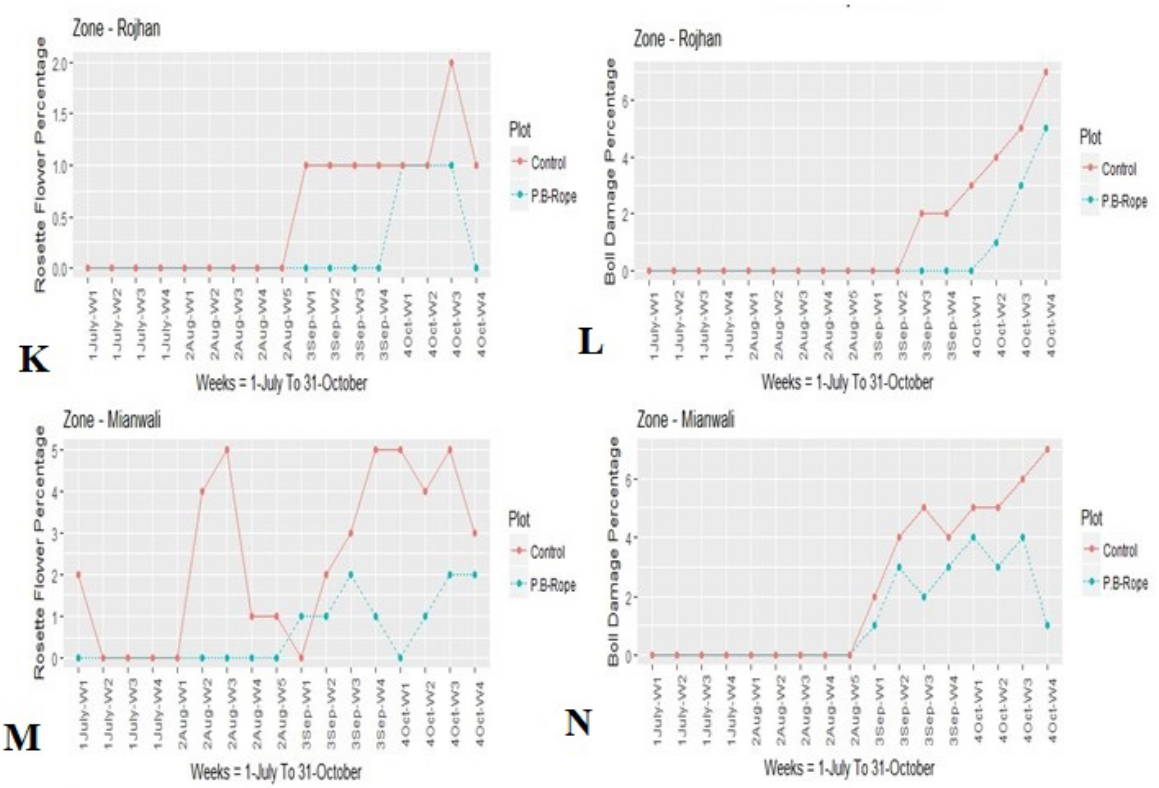

Figure 2(A-N): *Rosette flower and boll damage percentage by pink bollworm in control and PB rope plots of cotton in Mailsi, Burewala, Vehari, Rajanpur, Jampur, Rojhan and Mianwali.*

during 1st week of September (Figure 2G). The flower damage increased as the season advanced and peaked in October. The mean flower infestation in PB rope plots ranged from 0.0 to 1.0 percent compared to 0.0 to 3.0 percent in control. Significant differences with respect to boll damage were observed between the control and PB rope block (F = 7.17, P < 0.01) and among weeks (F = 8.2, P < 0.001) in Rajanpur. Bolls damage started in 3rd week of September and reached to maximum in October (Figure 2H). The mean boll damage in PB rope block ranged from 0.0 to 4.0 percent whereas boll damage ranged 0.0 to 6.0 in control.

Highly significant differences with respect to rosette flowers were observed between the control and PB rope blocks in Jampur (F = 42.43, P < 0.0001) whereas flower infestations in different weeks were statistically same (F = 1.09, P > 0.01). The flower infestation in PB rope block ranged from 0.0 to 2.0 percent whereas rosette flowers ranged 0.0 to 4.0 percent (Figure 2I). Flower infestation was recorded for first time in last week of August in control and peaked in September and October. In PB rope block, no flower infestation was observed during July, August and September. Flower damage ranged 1 to 2 percent during October. Significant differences with respect to boll damage were observed between the control and PB rope blocks (F = 9.5, P < 0.01) and among weeks (F = 4.95, P < 0.01) in Jampur. The mean boll damage in PB rope block ranged from 0.0 to 4.0 percent whereas boll damage ranged 0.0 to 7.0 percent in control. First damaged boll was observed in 2nd week of September and boll damage peaked (6%) in October in control (Figure 2J). Whereas, boll damage in PB rope block was observed only in October.

Significant differences with respect to rosette flowers were observed between the control and PB rope block (F = 8.73, P < 0.01) and among weeks (F = 3.49, P < 0.01) in cotton in Rojhan. Pink bollworm larva appeared 1st time in flower during 1st week of September in control (Figure 2K). The mean percentage of flower infestation in PB rope block ranged from 0.0 to 1.0 percent compared to control where rosette flowers ranged 0.0 to 2.0 percent in control. Significant differences with respect to boll damage were observed between the control and PB rope blocks (F = 8.2, P < 0.01) and among weeks (F = 8.4, P < 0.01) in Rojhan. Pink bollworm larva appeared 1st time in bolls during 2nd week of September in control plot and peaked in October (Figure 2I). The mean boll damage in PB rope block ranged from 0.0 to 5.0 percent compared to control where boll damage

ranged 0.0 to 7.0 percent.

Similarly, significant differences with respect to rosette flowers were observed between the control and PB rope block (F = 14.84, P < 0.01) in Mianwali. Whereas flower infestations in different weeks were statistically same (F = 1.66, P > 0.01). The mean percentage of flower infestation (Figure 2M) in PB rope block ranged from 0.0 to 2.0 percent compared to control where rosette flowers ranged 0.0 to 5.0 percent. Significant differences with respect boll infestation were also observed between the control and PB rope blocks (F = 6.8, P < 0.01) and among weeks (F = 6.5, P < 0.001) in Mianwali. Boll damage started in last week of August and peaked in September and October. The mean boll damage (Figure 2N) in PB rope block ranged from 0.0 to 4.0 percent compared to control where boll damage ranged 0.0 to 7.0 percent.

Significantly lower left over boll damage levels (F = 88.02, P < 0.001) were observed at time of harvest in PB rope blocks compared with control plots (Figure 3). There were no significant differences (F = 1.48, P > 0.01) in left over bolls damages among Tehsils and cotton varieties. Mean left over boll damage percentage in PB rope block ranged from 1.0 to 3.0 percent with a mean of 2.19 percent compared to 4.33 to 6.67 percent with mean of 5.95 percent in control. Yield was higher in PB rope plots as compared with control plots (Figure 4) in all Tehsils. Yield in PB rope plot ranged from 28.0 to 38 Monds per acre with average of 33.0 Monds per acre, while, in control plots yield ranged from 17.42 to 35.25 Monds per acre with average of 28.31 monds per acre.

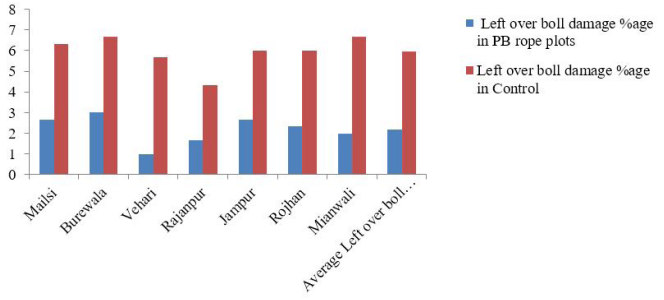

Figure 3: *Left over boll damage percentage by P. gossypiella larvae in control and PB-rope plots of cotton in different Tehsils of Punjab.*

Significantly lower moth catches were observed in PB rope plots compared to control in all ecological zones indicated potential of PB ropes technique for control of pink bollworm. PB rope dispensers were effective to cause reduction in trap catches for pink bollworm in cotton (Lykouressisa *et al.*, 2005). Mating suppression of 95- 100% by PB rope dispensers was reported in Israel (Kehat *et al.*, 1999). The mating suppression resulted in complete shutdown of moth catches in PB rope plots. An average of 0.8 moths/ trap/ night had been recorded in PB rope plots compared to 2.6/ trap / night in control plots (Patil *et al.*, 2004). Trap catches in gossyplure polyethylene tube dispenser fields recorded an average moth reduction of 94 to 98% compared to control and insecticide-treated cotton fields (Flint *et al.*, 1985). Whereas, PB rope dispenser manufactured by Shin-Etsu Chemical Co., Ltd., Tokyo, Japan resulted in 97% moth reduction in traps compared with pesticides treated fields (Staten *et al.*, 1987). PB ropes can effectively reduce pink bollworm in cotton. The reduction in moth catches and PBW damage is due to mating disruption among moths of pink bollworm preventing males from finding and mating with the females. This reduces the number of fertile eggs laid which reduces the population of the PBW resulting in less damage to the crop.

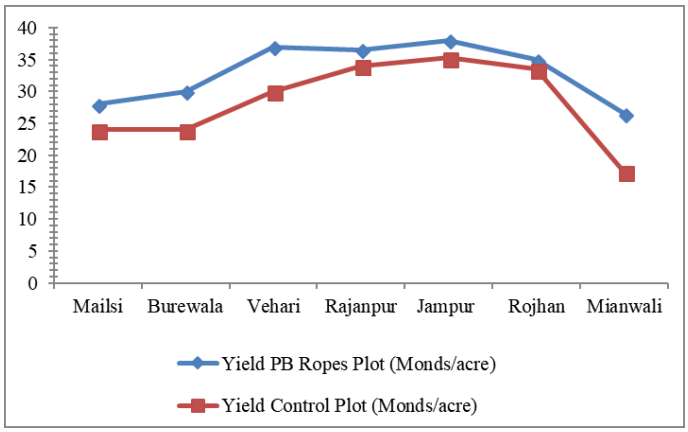

Figure 4: *Yield comparison in PB rope plots and control plots in different Tehsils of Punjab.*

High population densities of adults of pink bollworm were recorded during September and October. Pink bollworm infestation levels in the control fields were also higher than those in the PB rope fields during September and October. It has been reported in earlier investigations that pink bollworm population remained higher during August in Egypt (Crithcley *et al.* 1983). But its population peaked in September and October in Pakistan (Qureshi *et al.*, 1993). Early pheromone applications prevent population increase which may cause high loss in yield of cotton.

Three additional insecticide applications were used in control plots to keep PBW population below ETL

compared with PB rope plots where no insecticides were applied. It indicated that PB ropes significantly reduce no of sprays of insecticides against pink bollworm. PB ropes dispersers reduce 37 to 42% insecticides application in cotton fields (Staten *et al*., 1987). Pink bollworm can be managed properly with one application of pheromone and some insecticide sprays (Al-Deeb *et al*., 1993). Microencapsulated formulations of pheromone applications are equally effective to conventional pesticide sprays (Crithcley *et al*., 1983).

Our studies displayed comparatively lower damage percentage in left over bolls at time of harvest of cotton sticks and higher yield in PB rope plots compared with control (Sohi *et al*., 1999; Qureshi *et al*., 1985). Radhika and Reddy (2006) demonstrated that control plots recorded higher damage percentages of green bolls and left over bolls but lower cotton yield compared to PB ropes plots.

These investigations revealed that PB rope caused reduction in pink bollworm moth catches in traps and lowering the damage in cotton fields. It was found flower and boll damage percentages did not proportionally decrease compared to the decrease in trap catches in PB rope blocks. It may be due to mated females that enter from untreated fields to PB rope fields and lay eggs, the larvae emerging from these eggs infest flowers and damage bolls in cotton. Therefore, mating disruption of *P. gossypiella* must be regularly monitored for damage levels in the crop.

Conclusions and Recommendations

These results indicate PB rope L. dispensers play important role for control pink bollworm in cotton under field conditions. They will reduce no of insecticide sprays and increase per acre cotton yield. Use of PB ropes at large scale will effectively control pink bollworm and help to sustain cotton production in Pakistan. Therefore, it is recommended to commercialize PB ropes dispensers in the country. The farmers should be encouraged to use PB ropes against pink bollworm.

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Novelty Statement

PB Ropes (synthetic sex pheromones) dispensers play important role for control pink bollworm in cotton under field conditions by reducing no. of insecticide sprays and increasing per acre cotton yield. Hence, Use of PB ropes at commercial levels will surely control pink bollworm and help farming community to sustain cotton production in Pakistan.

Author's Contribution

KM, MRA and SIH: Conceived the idea, wrote introduction and materials and methods.
HA and MSA: Conducted experiments and wrote discussion.
AR, SAHN and UDU: Performed statistical analysis and wrote results while overall management was performed by MAZ.

Conflict of interest
The Authors have declared no conflict of interest.

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