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Effectiveness of nutrient elements in the management of fruit fly attacks on bitter gourd

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Abstract
The purpose of this study was to determine the efficacy of various nutrient elements (Mn, Zn, Cu, and B) in controlling the fruit fly that attacks bitter gourd. Two doses of four micronutrients, Manganese (3, 6 kg/ha), Zinc (6, 12 kg/ha), Boron (2, 4 kg/ha), and Copper (6, 12 kg/ha), along with an insecticide Diazinon (16.8 kg/ha) as a control, were tested to see how they affected flower initiation, percent fruit infestation in number and weight at early, mid, and late growing stages, percent damage, and yield performance. In addition, a chemical study of the soil was performed to determine the residual effect. Zinc had a substantial effect on bitter gourd flower initiation and number. Manganese 6kg/ha, Mn 3kg/ha, and Cu 12kg/ha were found to considerably lower the percent fruit fly infection by both number and weight. The effect of micronutrients on fruit fly pupation in bitter gourd plant soil did not vary significantly. Mn 6ka/ha treated plots produced the maximum yield (19.3t/ha), followed by Mn 3kg/ha (17.91 t/ha) and Cu 6kg/ha (16.70 t/ha) treated plots. The maximum yield increase above control (54.07 percent) was recorded in the Mn 6kg/ha treated plot, followed by the Mn 3kg/ha treated plot. The quantity of nutrient that remained in the soil at the end of the crop growing season ranged from 21.95 to 43.23 percent, with Mn (43.23 percent) being the highest. Based on the findings, manganese could be used as an IPM component to control fruit flies on bitter gourd.

Keywords: fruit fly, micronutrients, imp component, manganese, yield performance

Introduction
In Bangladesh, one of the most significant and well-liked cucurbit vegetables is the bitter gourd (Momordica charantia L.). The crop was first grown in India (Indo-Burma centre of origin). It is regarded as a favored vegetable among the cucurbits due to its high nutritional qualities, particularly ascorbic acid and iron [1]. The bitter gourd has a substance called charatin that is used to treat diabetes by lowering blood sugar levels [2]. In Bangladesh, the distribution of vegetable output throughout the year is uneven, with the bulk of it occurring in the winter [3]

The production of bitter gourd is hampered by a number of issues including diseases and insect pests that attack the plants. The red pumpkin beetle, the epilachna beetle, and the fruit fly are the three most significant pests that prevent the successful cultivation of bitter gourd. Damage caused by the fruit fly Bactrocera cucurbitae (Coquillett) (Diptera: Tephritidae) is the primary factor that prevents cucurbits from reaching their full potential in terms of yield. This is especially true for bitter gourd [4]. The cucurbit fruit fly is one of the most harmful pests to bitter gourds, producing output losses of between 30 and 100% [5, 6, 7].

Fruit flies have a preference for bitter gourd over other types of cucurbits; however, this preference is dependent on the species of cucurbit as well as the time of year. Fruit flies are one of the most common types of tropical fruit flies, and they can cause significant harm to cucurbits. A wide variety of crops belonging to the Cucurbitaceae family have been seen to be infested by the pest B. cucurbitae. It has been found that the percentage of fruit infested by fruit flies in bitter gourd ranges from 41 to 89 percent [8, 9, 10, 11, 4]. The fruits that were damaged when they were still in their early stages failed to develop normally and were eventually damaged and dropped.

Over the course of many years, a number of cucurbit fruit fly management strategies, including hydrolyzed protein spray, para-pheromone trap, spraying of ailanthus and cashew leaf extract, neem products, bagging of fruits, field sanitation, food baits, and spraying of chemical insecticides, have been utilized. One of these strategies is known as bagging of fruits [12, 13, 14, 15, 5, 16, 17]. These days, the only method that bitter gourd farmers in Bangladesh have at their disposal to combat pests is the application of poisonous insecticides. In certain regions, farmers spend roughly 25 percent of the total cost of cultivation on the purchase of poisonous pesticides. According to a study, pesticide residues were discovered in bitter gourd right next to brinjal. This led to a decrease in the amount of vegetables exported as a result of the major worry of the countries that were importing

them [3]. In addition, the continued use of poisonous insecticides has created a situation that is hazardous not only for the environment but also for the health of farmers and consumers. As a consequence of this, the Environmental Protection Agency has recently been pushing for a reduction in the application of dangerous pesticides, particularly organophosphates, organochlorines, some carbamates, and pyrethroides, in agricultural crops. The use of an integrated pest management (IPM) strategy has recently become more popular as a method for the control of fruit flies [18]. The term "integrated pest management" (IPM) refers to the practice of combining several methods of pest control, such as chemical, biological, and cultural approaches; yet the use of insecticides remains an essential component of such approaches. When surface application of insecticides is used, the maggots of fruit flies frequently pupate either in the soil, inside the fruits, or under the debris, which allows them to escape being exposed to or coming into touch with the insecticides. In the same way, maggots damage the inside of the fruit. Because of this, developing fruit varieties that are resistant to fruit fly is an important part of an integrated pest management plan for this pest [19].
Consequently, it is desirable to explore alternative control strategies and design a management approach for fruit fly that is effective, less expensive, and less harmful to the environment because unfortunately no single technique has so far been showed to be an effective and dependable to control this pest [20]. It is possible to influence the plant's vulnerability to insect pests by using cultural measures such as crop fertilization. A nutrient is a mineral that crops must consume in appropriate quantities in order to function properly. Use of nutrients is both environmentally friendly and very desirable because they are naturally occurring substances. It is possible that changes in nutrient levels can alter the environment in a way that benefits insects. There are a few cases where nutrients can actually modify a plant's genetic resistance to insects. Compared to nitrogen, potassium fertilizer appears to have a detrimental impact on the number of insects. Proteogenesis, a physiological mechanism associated with the removal of amino acids and the reduction of sugars in sap, is to blame for this, as plants have a higher level of proteogenesis. Insect pest and disease resistance in crop plants is one of the best soil qualities, according to research. In order for crops to take up and use micronutrients, they must consume them in extremely minute amounts. Alloys of these metals include copper, zinc, iron, manganese, molybdenum, and chlorine (Cl). Zn and B deficiencies in Bangladeshi soil are particularly severe in low-lying areas and waterlogged soil, where Zn deficiency is particularly acute. Zn deficiency was detected frequently in calcareous soils. Sandy, well-drained soils with limited water retention capacity were found to be deficient in boron [21,22]. Many countries, including Bangladesh, suffered from a lack of boron and zinc. Crops in Asia are suffering from copper deficiency. Micronutrient deficiency is becoming an increasingly serious issue, and it is affecting crop production [23]. Numerous studies reveal that soil nutrient changes influence insect damage and antibiosis and antibiosis factor of resistance expression. Generic resistance testing requires that nutrient regimes be comparable to the recommended nutrient levels in the cropping system [24]. There are various factors that influence pest species' ability to successfully colonize a host plant. These include changes in plant growth rates, rapid or delayed maturation, changes in plant component size, thickness, and hardness, all related to the application of fertilizers. So, considering the above-mentioned points this study was conducted with the following objectives:

- to evaluate the effect of nutrient elements on flower and fruit, and infestation by fruit fly in bitter gourd and
- to find out sustainable component of IPM by exploiting nutrient elements for the management of fruit fly.

Materials and Methods

The study was conducted in the experimental field of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU) Salna, Gazipur. In order to evaluate the effectiveness of nutrient element for the management of fruit fly attacking bitter gourd (*Momordica charantia Linn*) under field condition the following treatments, their application procedures and methodologies undertaken in this study are described below:

1. Soil and climate

The experimental site was situated in the sub-tropical climatic zone. The soil of the experimental land was silty clay loam texture, soil type grey terrace and belongs to the agro ecological zone of Madhupur tract (AEZ-28) with PH 5.8 to 6.5 [25].

2. Location

The area of experiment was situated at 24.09N latitude and 90.26E longitudes with an elevation of 8.4 meter from the sea level.

3. Design of experiment

The study was conducted with the eight micronutrients treatments, an insecticide and a control laid out in a Randomized Complete Block Design (RCBD) with 3 replications.

4. Raising Seedling

Seeds of “BARI corolla-1” variety were collected from Bangladesh Agriculture Research Institute (BARI) Joydebpur, Gazipur. Seeds were soaked for 48 hours in water for breaking dormancy and then 1 seed were sown in each polybag containing 50% well decomposed cow dung and 50% sandy loam soil. Numbers of seeds sown were 250. After fourteen days seeds were germinated and one-month old seedling was transplanted in the field after land preparation.

5. Land preparation and fertilization

The land was prepared thoroughly by ploughing followed by laddering to attain a good tilth. Weeds and stubbles were removed and the land was finally prepared by additional of basal doses of fertilizers and well decomposed cowdung. The size of each experimental plot was 3m x 2m with plot-to-plot distance 1m and block to block distance 2m. The whole experimental field was divided into 30 plots to accommodate 3 replications having 3 plants in each plot. Therefore, there were 90 plants in the whole experiment. Cowdung and other fertilizers were applied as recommended by Rashid (1993) [26] for bitter gourd. Cowdung, urea, TSP, MP were applied @ 10000 kg, 125 kg and 100 kg per hectare, respectively. The total cowdung, two third of TSP and one third of urea were applied as basal dose during land preparation. The rest of the TSP and half of MP were applied in the pits seven days before transplanting of seedling. The remaining portions of urea and MP were top dressed after each three flush of flowering and fruiting in two equal splits.

6. Cultural practices

After transplanting, the seedlings were provided with irrigation. Stacking of each plant using bamboo stick was done few days after transplanting to facilitate creeping of plant and also to avoid lodging. All the bamboo sticks were tightened with long wire and rope. Irrigation, top dressing of urea (@ 10g/plot/application) and weeding were done as and when necessary for proper development.

7. Treatment application

The normal doses of Cu, Zn, Mn and B used by Lorenz and Maynard (1988) [27] were 6, 6, 3 and 2 kg/ha respectively in the form of Copper sulfate, Zinc sulfate, Manganese sulfate and Boric Acid. According to Lorenz and Maynard, the treatments of this experiment were selected which is used as 100% and 200% of normal dose. The treatments used are given in Table 1.

Table 1: Treatments of micronutrients applied at different doses in the field

Element	Doses
Mn	3kg/ha
Mn	6kg/ha
Zn	6kg/ha
Zn	12kg/ha
B	2kg/ha
B	4kg/ha
Cu	6kg/ha
Cu	12kg/ha
Diazinon 5G	16.8kg/ha
Control	Untreated

The micronutrients were applied the plots subsequently in two splits. First application of micronutrients was done by mixing with soil before four days of transplanting and second application of treatment was done after 1st flower opening followed by mixing with soil. When the second split of micronutrients were applied Diazinon 16.8 kg/ha also applied. The plots of untreated control were left without any application of micronutrients and insecticide. The intercultural operations were similar in all the plots.

8. Data recording

For evaluation of target parameters, different types of data were recorded for fruit fly infestation attacking those cucurbit fruit vegetables. Details of the data recording procedures are explained under the following sub-heading.

9. Flower initiation and number of flowers

Data on flower initiation and number of flowers were taken at early, mid and late stages under 40 cm from the tip of the vine. Three vines were counted from each plot. Plants were observed from 2nd week of planting, the duration of flower initiation and number of flowers of each plot was recorded.

10. Percent fruit infestation by number

Fruit infestations were taken at early, mid and late fruiting stages. During these stages a total of 7 harvests were done. At the early fruiting stage, three harvests were done, and other stages consist of 2 harvest. Fruits were harvested at an interval of 8 days. After harvesting the healthy fruit (HF) and the infested fruits (IF) were separated by visual observation. The number of healthy fruits and infested fruits were counted and the percent fruit infestation for each treatment was calculated by using the following formula:

$$\% \text{ Fruit infestation by number} = \frac{\text{Number of IF}}{\text{No. of HF} + \text{No. of IF}} \times 100$$

11. Percent fruit infestation by weight

After harvest at each fruiting (early, mid and late) stage, the total fruits were sorted into healthy and infested ones for each treatment. On the basis of weight of healthy fruit (HF) and infested fruit (IF) the percent fruit infestation by weight was calculated using following formula:

$$\% \text{ Fruit infestation by weight} = \frac{\text{Weight of IF}}{\text{Weight of HF} + \text{Weight of IF}} \times 100$$

12. Percent fruit damage

After harvest at each fruiting (early, mid and late) stage the total infested fruits were cut and sorted the maximum healthy portion of that fruit for each treatment. Percent fruit damage for each treatment was calculated by using the following formula:

$$\% \text{ Fruit Damage} = \frac{\text{Weight of infested portion}}{\text{Weight of healthy portion} + \text{Weight of infested portion}} \times 100$$

13. Number of pupae

Number of pupae was collected from each plot using a quadrate (30 X 30 cm^2 and 5cm depths) by dry sieving method. At first quadrate was placed then, 5cm deep soil was collected. After sieving pupae were separated from soil and numbers of pupae were recorded.

14. Total yield

The cumulative plot yield of healthy, infested and total fruits of all harvests were transformed into marketable, infested and total yield per ha in tons, respectively.

15. Soil sampling

Nine samples were collected from each 3 block before application of micronutrient and after completion of harvest the analysis of micronutrients (Zn, Cu, Mn, and B) was done.

16. Preparation of soil samples

Soil samples were sun dried after collection from the field. Then sieving and grinding was done by sieve and grinder respectively.

17. Copper, Zinc, analysis of soil samples

- Two and half g (2.5) of each sample was taken into six different conical flasks.
- Twenty-five ml of 0.1M Hydrochloric acid was added to each sample and then the sample was stirred with the help of stirrer for 45 minutes.
- Then the sample was filtered with filter paper.
- Reading was taken for each sample with the help of Atomic Absorption Spectrophotometer and calculated the percent of Cu, Zn and Mn using the following formula:

Zn/Cu (ppm): - (S-B) X Dilution Factor X Concentration Factor

Here,
S- Sample absorbance
B- Blank absorbance

18. Boron Analysis

Boron analysis was carried out by the following steps:

- Ten (10) g of soil sample was taken into six different conical flasks and 50 ml calcium phosphate solution was added to each sample. Then the sample was shaken with rotary shaker for 30 minutes.
- After shaking, the samples were filtrated with filter paper
- One fourth of ml (0.25) of filtrate was taken into six different plastic bottles.
- Two ml Curcumine and 0.5 ml of Sulfuric acid was added and allow standing 35 minutes.
- Then 15 ml of Methanol was added into each solution and reading was taken with the help of Double Beam Spectrophotometer. Percent B was calculated using the formula:

B (ppm): - (S-B) X Dilution Factor X Concentration Factor

Here,
S- Sample absorbance
B- Blank absorbance

19. Manganese Analysis
Mn analysis was done through following steps:

- Five g (5) soil sample was taken in a conical flask and 50 ml of ammonium acetate solution was added to the sample and then shaking was done continuously for 30 minutes on a mechanical shaker and then intermittently for at least 6 hours.
- The soil mixture was filtered through a filter paper
- Ten ml (10) of clear solution was taken with the help of a pipette into a 250 ml beaker and the beaker was placed on a hot plate.
- Then the solution was evaporated to dryness on a hot plate and continued to be heated until the NH_4OAC was made to fume. After cooling the beaker 5 ml of HNO_3 and 2 ml of 30% H_2O_2 were added. The beaker was covered with a watch glass and again digestion was done for 30 minutes to destroy the organic matter.
- Removing the cover glass, evaporation was done until dryness.
- Twenty ml (20) of H_2O_2, 2 ml of HNO_3 and 5 ml of 85% H_3PO_4 were added. For the shortage of KIO_4, it was not added in the mixture.
- Then again, the solution was digested and cooled those solutions in room temperature and transferred the solution to 100 ml of volumetric flask. Then shaking was done and reading was taken at 540 nm absorbance. Calculation was done using the following formula:

Manganese (ppm): (S-B) X Dilution Factor X Concentration Factor

Here,
S- Sample absorbance
B- Blank absorbance

20. Data analysis
The recorded data were analyzed by using MSTAT computer program for the analysis of co-efficient of variance. ANOVA was done and means were separated by using LSD after necessary transformation of data.

Results and Discussion
The effectiveness of some micronutrients (Mn, Cu, Zn, B) along with a check Diazinon (5G) and an untreated control for management of fruit fly attacking bitter gourd are presented with relevant discussion under the following subheading:

1. Flower initiation and number of flowers
Plants were observed from second week of planting, the days for flower initiation and number of flowers of each plot was recorded. The days of first flower initiation in different plots ranged 55.00 – 56.67 DAS which do not vary markedly. The first flower initiation was recorded in the plot treated with Zn at 6kg/ha after 55 DAS. It was observed that the flower initiation in bitter gourd was little bit earlier in case of lower doses of micronutrients. After sowing the range of flower initiation days in Mn, Cu, Zn, B, Diazinon 5G and control plot was 55.67-56.33, 55.67-56, 55-55.33, 56-56.33, 56.67 and 56.67 DAS, respectively (Figure 1). The flower initiation delayed a little bit in case of highest doses of Mn and Cu. There is no significant difference in flower initiation days. The higher doses of micronutrient delay flowering which might be due to higher micronutrient meddling in florigen production [28]. Higher doses of micronutrient applied after 31 days of normal doses which might be one reason of delayed flower initiations and soil doesn't accumulate these nutrients properly resulting delayed flower initiation.

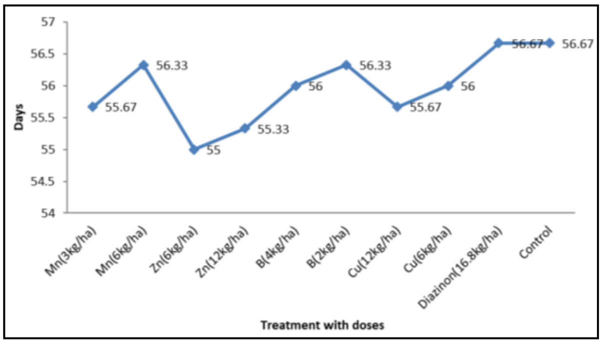

Fig 1: Effect of selected micronutrients on flower initiation days after sowing (DAS) in bitter gourd

The number of flower (40 cm top vine) in all the plots during the entire cropping season utilizing micronutrients ranged from 11.67 to 25.67 (Table 2). At early stage the highest number (4.00) of flower was observed in Zn 12kg/ha and Mn 6kg/ha treated plots which were statistically similar with the treated plots of Cu two doses including control plot. The lowest number of flower was observed in Mn 3kg/ha treated plot which is statistically similar to that of Zn 6kg/ha, B treated plots having two doses.

At mid growing stage, highest number (9.00) of flower was observed in Zn 12kg/ha treated plot which was statistically similar with B 2kg/ha treated plot. The lowest number (4.33) of flower was recorded in Mn 3kg/ha treated plot which was not significantly different from that of Mn 6kg/ha, Zn 6kg/ha, Cu, B 4kg/ha, Diazinon and control plot. At late growing stage the highest number of flowers was recorded (12.67) from Zn 12kg/ha treated plot which was significantly different from all other treatments. The lowest number (5.67) of flower observed in Mn 3kg/ha

Table 2: Effect on number of flowers of bitter gourd at early, mid, late stages of bitter gourd

Treatment with doses	Number of flowers			
	Early stage	Mid stage	Late stage	Total
Mn(3kg/ha)	1.67d	4.33c	5.67d	11.67e
Mn(6kg/ha)	4.00a	4.67c	7.67cd	16.33cd
Zn(6kg/ha)	2.33bcd	6.33bc	10.00b	18.67bc
Zn(12kg/ha)	4.00a	9.00a	12.67a	25.67a
B(2kg/ha)	2.33bcd	7.67ab	10.00b	20.00b
B(4kg/ha)	2.33bcd	6.00bc	6.67cd	15.00d
Cu(6kg/ha)	3.67ab	6.33bc	10.00b	20.00b
Cu(12kg/ha)	3.33abc	5.00c	7.67cd	16.00cd
Diazinon(16.8kg/ha)	2.00cd	4.67c	8.00bc	14.67de
Control	3.33abc	5.00c	8.67bc	17.00bcd
LSD value	1.45	2.56	2.15	3.30
Significance level	*	*	*	*
CV	7.78	10.09	9.45	8.63

* Means are separated by LSD at 5 percent level of significance

Treated plot which was statistically similar to that of Mn 6kg/ha and Cu 12kg/ha treated plots. The number of flower in all stage during the whole season was the highest (25.67) in Zn 12kg/ha treated plot and the lowest number (11.67) of flowers was found from Mn 3kg/ha treated plot which was statistically similar with those of insecticide treated plots. Higher dose of Zn produced higher number of flowers, that might be increased femaleness and dcreased maleness [29]. Zinc also accumulate soil quickly and function in plants which induced the higher number of flowers populatoin [30].

2. Fruit infestation by number at early growing stage

After harvesting, healthy and infested fruits were separated by visual observation. Infested fruits were physically damaged and truned yellow to brownish in color. At early stage, the number of infested fruits ranged from 21.67 – 37.33. The lowest number of infested fruits (21.67) was in Cu 12kg/ha treated plot (Table 3). It was found that the highest number of infested fruits (37.33) were found in Zn 12kg/ha and Cu 6kg/ha treated plots. The highest number of healthy fruits (35.67) was recorded in Mn 3kg/ha treated plot and untreated control plot had the lowest number of healthy fruits (16.33). The percent infested fruits at early stage of bitter gourd ranged from 41.29 – 64.72%. The lowest percent of infested fruits (41.29%) was obtained in Cu 12 kg/ha treated plot which was significantly lower than all other treatments. On the other hand, the highest percent of infested fruits (64.72%) was harvested from untreated control plot. The lowest percent infestation in bitter gourd was in Cu 12 kg/ha might be due to the higher toxicity of Cu [31]. Percent reduction of fruit infestation over control was ranged from 17.22 - 36.20 %. The highest percent reduction of infested fruits by number over control at early stage was (36.20%) found in Cu at 12 kg/ha treated plot. The lowest percent reduction of infestation was calculated from Diazinon 16.8 kg/ha treated plot.

Table 3: Number of infested and healthy fruits per plot at early growing stage including the rate of infestation and its percent reduction over control in different treatments

Treatment with doses	Infested Fruit	Healthy Fruit	Total Fruit	% Fruit infestation	% Reduction over control
Mn (3kg/ha)	33.00	35.67	68.67	46.49ef	28.17
Mn(6kg/ha)	22.33	28.00	50.33	45.74f	29.33
Zn(6kg/ha)	27.33	27.67	55.00	50.83c	21.46
Zn(12kg/ha)	37.33	34.00	71.33	50.26cd	22.34
B(2kg/ha)	33.67	34.67	68.33	48.12de	25.65
B(4kg/ha)	26.67	26.33	53.00	51.07bc	21.09

Cu(6kg/ha)	37.33	35.33	72.67	53.25b	17.72
Cu(12kg/ha)	21.67	25.67	47.33	41.29g	36.20
Diazinon(16.8kg/ha)	36.00	30.00b	66.00	53.29b	17.66
Control	29.67	16.33	46.00	64.72a	
LSD value				2.33	
Significance level				*	
CV	7.87	9.12	11.63	6.55	

* Means are separated by LSD at 5 percent level of significance

Table 4: Weight of infested and healthy fruits per plot (g) at early growing stage including the rate of infestation and its percent reduction over control in different treatments

Treatment with doses	Infested Fruit	Healthy Fruit	Total Fruit	%Fruit Infestation	% Reduction over control
Mn(3kg/ha)	1466.67	2850.00	4316.67	33.41de	34.45
Mn(6kg/ha)	800.00	2166.67	2966.67	26.71f	47.60
Zn(6kg/ha)	1023.33	2233.33	3256.67	34.75cde	31.83
Zn(12kg/ha)	1450.00	2350.00	3800.00	37.16c	27.10
B(2kg/ha)	1193.33	2423.33	3616.67	33.73cde	33.84
B(4kg/ha)	1216.67	1816.67	3033.33	42.00b	17.61
Cu(6kg/ha)	1480.00	3326.67	4806.67	35.53cd	30.31
Cu(12kg/ha)	1306.67	2866.67	4173.33	31.64e	37.93
Diazinon(16.8kg/ha)	1183.33	2966.67	4150.00	32.73de	35.79
Control	1416.67	1350.00	2766.67	50.98a	
Significance level				*	
LSD value				3.53	
CV	9.97	5.76	12.33	4.67	

* Means are separated by LSD at 5 percent level of significance

3. Fruit infestation by weight at early growing stage

At early stage, infested fruits by weight ranged 800g -1466.67g with the lowest (800g) being in Mn 6kg/ha and the highest weight (1466.67g) in Mn 3kg/ha treated plots (Table 4). The highest weight of healthy fruits (3326.67g) was found in Cu 6kg/ha treated plot. The lowest weight of healthy fruits (1350.0g) was recorded in untreated control plot. The lowest percent (26.71%) of infested fruits of bitter gourd by weight was observed in Mn 6kg/ha treated plot which was significantly higher than any other treatments. The highest percent of infested fruits by weight were obtained from untreated control plot which was statistically different from all other treatments because these plots might be more palatable to fruit fly.

The reduction of percent infestation by weight at early growing stage of bitter gourd ranged 47.60 – 17.61% (Table 4). The highest reduction of percent infested fruits over control by weight was (47.60%) found in Mn 6kg/ha treated plots [32] and the lowest (17.61%) reduction over control was found in B 4kg/ha treated plots.

Table 5: Number of infested and healthy fruits per plot at mid growing stage including the rate of infestation and its percent reduction over control in different treatments

Treatment	Infested Fruit	Healthy Fruit	Total Fruit	%Fruit Infestation	% Reduction over control
Mn(3kg/ha)	25.67	39.33	65.00	42.71d	26.61
Mn(6kg/ha)	31.67	39.67	71.33	43.23d	25.72
Zn(6kg/ha)	33.33	27.33	60.67	53.87b	7.43
Zn(12kg/ha)	31.33	32.67	64.00	48.17c	17.23
B(4kg/ha)	36.67	24.33	61.00	54.31b	6.68
B(2kg/ha)	38.33	30.00	68.33	56.10ab	3.60
Cu(12kg/ha)	27.00	26.67	53.67	43.52d	25.22
Cu(6kg/ha)	27.00	28.00	55.00	50.56c	13.13
Diazinon(16.8kg/ha)	25.33	32.00	57.33	43.49d	25.27
Control	48.67	35.33	84.00	58.20a	
Significance level				*	
LSD value				2.66	
CV	7.28	6.62	6.34	9.43	

* Means are separated by LSD at 5 percent level of significance

4. Fruit infestation by number at mid growing stage

At mid growing stage, healthy fruits by number were ranged from 24.33- 39.67. The highest number of healthy fruits (39.67) was harvest from Mn 6kg/ha treated plot followed by Mn 3kg/ha treated plots (Table 5). The lowest number of healthy fruits (24.33) was obtained in B 4kg/ha treated plot followed by Cu 12kg/ha and Zn 6kg/ha treated plots. The infested fruits at mid growing stage ranged from 25.33 - 48.67 with total number ranged from 53.67 - 84.00.

The lowest percent infestation (42.17%) was found in Mn 3kg/ha treated plot which was statistically similar to that of Mn 6kg/ha, Cu 12 kg/ha and Diazinon 16.8 kg/ha treated plots. And the highest infested fruits (58.20%) were recorded in untreated control plot. It was observed that at early and mid-stage Cu 12kg/ha and Mn 6kg/ha treated plots had less rate of infestation than other micronutrient treated plots and control plot gave higher rate of infestation.

Reduction of percent infestation over control at mid stage of bitter gourd by number was ranged from 3.60 - 26.61% with the highest being (26.61%) in Mn 3kg/ha treated plot. The lowest percent reduction of infestation (3.60%) over control was observed in B 2kg/ha treated plot (Table 5).

5. Fruit infestation by weight at mid growing stage

At mid stage, the healthy, infested and total fruits by weight were ranged from 1583 - 3138g, 1083.33 - 2200g and 2111.11 - 4244.44g, respectively (Table 6). The highest weight of healthy fruits (3183.33g) was found in Diazinon 16.8 kg/ha treated plot and the lowest healthy fruits (1583.33g) was in untreated control plot. It is found from Table 6 that the lowest percent of infested fruits (28.77%) was in the Mn 6kg/ha treated plot followed by Diazinon 16.8kg/ha (31.48%) and Mn 3kg/ha (32.05%) treated plots. Mn 6kg/ha, Diazinon 16.8 kg/ha and Mn 3kg/ha had significant effect on reducing the percent fruit infestation compared to untreated control plot.

Infestation reduction over control at mid stage by weight was ranged from 3.08 - 35.81%. The highest reduction over control (35.81%) was found in Mn 6kg/ha treated plot. And the lowest infestation reduction over control (3.08%) was observed in B 2kg/ha treated plot (Table 6).

Table 6: Weight of infested and healthy fruits per plot (g) at mid growing stage including the rate of infestation and its reduction over control in different treatments

Treatment with doses	Infested fruit	Healthy fruit	Total Fruit	%Fruit infestation	% Reduction over control
Mn(3kg/ha)	1166.67	2766.67	3688.89	32.05de	28.49
Mn(6kg/ha)	1083.33	2650.00	3533.33	28.77e	35.81
Zn(6kg/ha)	1250.00	2233.33	2977.78	35.53bc	20.72
Zn(12kg/ha)	1616.67	2733.33	3644.44	37.13b	17.16
B(2kg/ha)	2200.00	2900.00	3866.67	43.44a	3.08
B(4kg/ha)	1633.33	2116.67	2822.22	42.80a	4.51
Cu(6kg/ha)	1216.67	2383.33	3177.78	37.25b	16.89
Cu(12kg/ha)	1383.33	2250.00	3000.00	33.10cd	26.15
Diazinon(16.8kg/ha)	1450.00	3183.33	4244.44	31.48de	29.76
Control	1450.00	1583.33	2111.11	44.82a	
Significance level				*	
LSD value				3.45	
CV	11.21	10.54	7.70	6.55	

* Means are separated by LSD at 5 percent level of significance

6. Fruit infestation by number at late growing stage

At late growing stage, the highest number of healthy fruits (38.33) was found in Cu 6kg/ha treated plot. And the lowest number of healthy fruits (20.00) was observed in B 4kg/ha treated plot (Table 7). The lowest infestation (12.00) was obtained in Mn 3kg/ha and the highest infestation (28.33) was observed in Zn 12kg/ha treated plot. It was observed that Mn showed better performance at late stage of plant growth. Percent infested fruits at late stage of bitter gourd ranged 34.29 – 55.27%. The lowest percent infested fruits (34.29%) were harvest from Mn 6kg/ha treated plot which was statistically similar to that of Mn 3kg/ha treated plot. The highest percent of infested fruits (55.27%) were found in untreated control plot which was significantly different from all other treatments.

Table 7: Number of infested and healthy fruits per plot at late growing stage including the rate of infestation and its percent reduction over control indifferent treatments

Treatment	Infested Fruit	Healthy Fruit	Total Fruit	%Fruit Infestation	% Reduction over control
Mn(3kg/ha)	12.00	24.33	30.00	36.36gh	34.21
Mn(6kg/ha)	16.33	33.00	33.67	34.29h	37.96
Zn(6kg/ha)	20.67	22.00	48.00	50.63b	8.39
Zn(12kg/ha)	28.33	37.33	65.67	42.18e	23.68
B(2kg/ha)	21.33	25.33	60.33	45.51cd	17.66

B(4kg/ha)	16.00	20.00	36.00	41.00ef	25.82
Cu(12kg/ha)	18.00	22.00	56.00	44.11de	20.19
Cu(6kg/ha)	22.00	38.33	39.33	38.31fg	30.68
Diazinon(16.8kg/ha)	22.33	25.67	29.11	51.67b	6.51
Control	27.00	20.67	39.11	55.27a	
Significance level				*	
LSD value				3.36	
CV	6.33	11.02	9.76	5.50	

* Means are separated by LSD at 5 percent level of significance

The highest fruit infestation reduction (37.96%) over control at late stage of crop growth was found in Mn 6kg/ha treated plot which was followed by Mn 3kg/ha (34.21%) and Cu 6kg/ha (30.68%) treated plots. The lowest percent reduction (6.51%) over control was found in Diazinon 5G at 16.8kg/ha treated plot.

7. Fruit infestation by weight at late growing stage

Maximum weight (2516.67g) of healthy fruit was observed in Mn 3kg/ha treated plot. Minimum weight (1000g) of healthy fruits was obtained in B 4kg/ha treated plot (Table 8). Total weight of fruits was the highest (3700g) in Mn 3kg/ha treated plot. The percent of infested fruits of bitter gourd at late growing stage of the crop ranged from 29.43 – 48.98% (Table 8). Significantly the lowest percent of infested fruits was recorded in Mn 6kg/ha treated plot which was similar to that of Zn 12kg/ha (30.01%) and Mn 3kg/ha (31.68%) treated plots. On the other hand, significantly the highest percent of infested fruits (48.98%) was found in control plot. It can be said from result that Mn treated plot performed better than all other treatment. Sometimes check Diazinon 16.8 kg/ha performed poorly compared to untreated control. The information of higher infestation in the plot treated with Diazinon 16.8 kg/ha is unknown.

The highest reduction of infested fruits (39.73%) by weight over control at late stage was found in Mn 6kg/ha treated plot which was followed by Zn 12kg/ha (38.73%) and Mn 3kg/ha (35.32%) treated plot. The lowest percent reduction of infestation (7.78%) was found in Diazinon 16.8kg/ha treated plot (Table 8).

Table 8: Weight of infested and healthy fruits per plot (g) at late growing stage including the rate of infestation and its percent reduction over control in different treatments

Treatment with doses	Infested fruit	Healthy fruit	Total Fruit	%Fruit infestation	% Reduction over control
Mn(3kg/ha)	1183.33	2516.67	3700.00	31.68fg	35.32
Mn(6kg/ha)	800.00	1933.33	2733.33	29.43g	39.73
Zn(6kg/ha)	750.00	1716.67	2466.67	37.74cd	22.94
Zn(12kg/ha)	466.67	1533.33	2000.00	30.01g	38.73
B(2kg/ha)	716.67	1766.67	2483.33	36.05de	26.39
B(4kg/ha)	616.67	1000.00	1616.67	34.32e	29.93
Cu(6kg/ha)	1033.33	2350.00	3383.33	33.79ef	31.01
Cu(12kg/ha)	950.00	1466.67	2416.67	38.85c	20.68
Diazinon(16.8kg/ha)	916.67	1900.00	2816.67	45.17b	7.78
Control	1416.67	1400.00	2816.67	48.98a	
Significance level				*	
LSD value				2.33	
CV	9.76	12.87	15.36	6.07	

* Means are separated by LSD at 5 percent level of significance

8. Percent fruit infestation by number and weight at early, mid and late stage of crop

The percent infestation of fruits by both number and weight was higher in late stage than the mid and early growing stages (Figure 2). It was also found from Figure 2 that the rate of fruit infestation by number and weight at early mid and late growing stages was the highest in the untreated control plots.

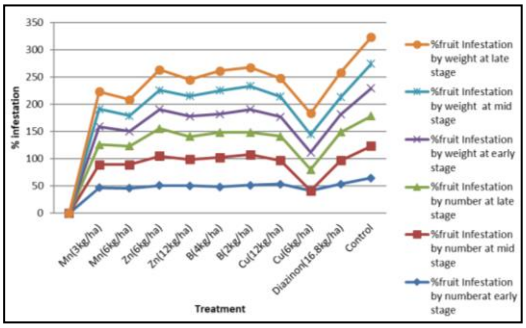

Fig 2: Percent fruit infestation by number and weight at early, mid and late stage of crop growth

Percent fruit infestation was the highest by number (64.72%) recorded in untreated control plot at early stage (Figure 2). Percent fruit infestation was the lowest (34.29%) in Mn 6kg/ha treated plot at late stage along with Mn 3kg/ha and Cu 6kg/ha treated plots. With the treatments of Mn 6kg/ha, Mn 3kg/ha and Cu 6kg/ha the fruit infestation was decreased but in untreated control, Zn 6kg/ha and Diazinon 16.8 kg/ha treated plots had increased fruit infestation. On the other hand the percent infestation by weight was the lowest (26.71%) in Mn 6kg/ha treated plot at early stage [32].

Table 9: Percent damaged fruits by fruit fly infestation at different stages of bitter gourd

Treatment with doses	% damage at early growing stage	% damage at mid growing stage	% damage at late growing stage	% damage in total
Mn(3kg/ha)	50.13 e	80.30bc	63.69b	64.18de
Mn(6kg/ha)	45.07f	70.06e	56.44c	59.14f
Zn(6kg/ha)	68.54bc	76.81cd	76.51a	74.37ab
Zn(12kg/ha)	70.82b	71.66e	64.85b	71.77bc
B(2kg/ha)	76.40a	81.48b	71.73a	66.70d
B(4kg/ha)	74.32a	83.11b	59.91bc	70.55c
Cu(6kg/ha)	68.00bc	76.87cd	72.02a	74.08b
Cu(12kg/ha)	65.49c	72.35e	64.39b	61.08ef
Diazinon(16.8kg/ha)	59.98d	72.94de	74.44a	74.64ab
Control	77.30a	87.38a	75.27a	77.66a
Significance level	*	*	*	*
LSD value	3.45	4.16	6.19	3.44
CV	6.66	7.34	8.32	10.10

* Means are separated by LSD at 5 percent level of significance

9. Percent damaged fruits by fruit fly infestation at different stages of bitter gourd

From the infested fruits, percent damaged fruits were calculated. At the early stage, percent damaged fruits in Mn 6kg/ha treated plot was the lowest (45.07%) which significantly lower than all others micronutrient treated plots (Table 9). The highest percentage of damaged fruits (77.30%) were found in control plot which was not significantly different from that of B treated plot with two doses. At mid stage, percent damaged fruits was the lowest (70.06%) in Mn 6kg/ha treated plot along with Cu 12kg/ha (72.35%), Zn 12kg/ha (71.66%), Diazinon 16.8 kg/ha (72.94%) treated plots and they were statistically similar (Table 9). The highest damage (87.38%) was observed in untreated plot which was significantly higher than the other treated plots. At late stage, the lowest damage (56.44%) was found in Mn 6kg/ha treated plot which was statistically similar to that of B 4kg/ha treated plot. The highest damage (76.51%) observed in Zn 6kg/ha treated plot in this stage along with B 2kg/ha, Diazinon, Cu 6kg/ha, and control plots. Total percent damaged fruits were the lowest (59.14%) in Mn 6kg/ha treated plot which was statistically similar to that of Cu 6kg/ha treated plot. The highest damaged fruits were recorded in (77.66%) in untreated control followed by Diazinon 16.8 kg/ha (74.64%) and Zn 6kg/ha (74.37%).

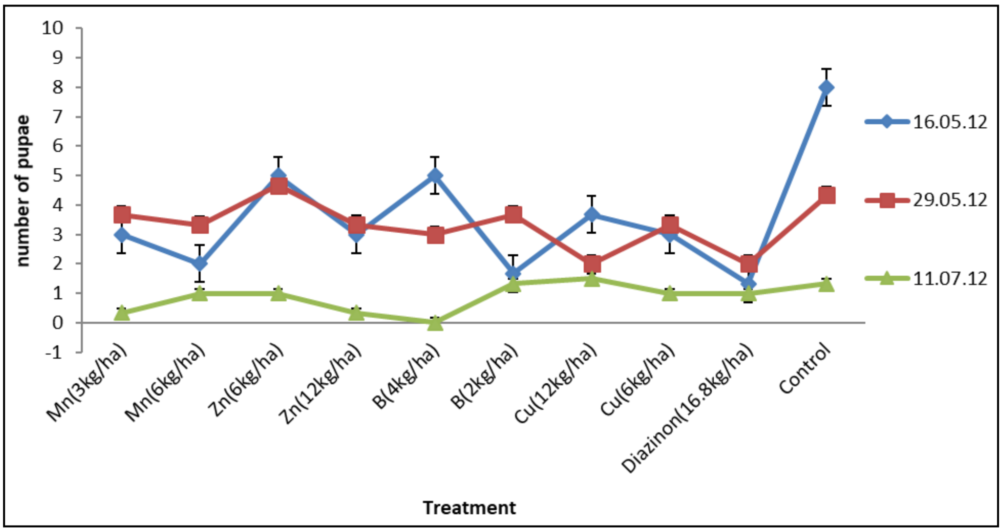

Fig 3: Effect of selected micronutrients on the pupation of fruit fly in soil of bitter gourd plots

Number of pupae

The number of pupae in soil of all the treated and untreated control plots was lower in last observation at late stage than the earlier stage of observation (Figure 3). The highest number of pupae was obtained in untreated control plot besides all the other observations. Figure 3 indicates that the highest number of pupae (8) was found in control plot in 16 May which was significantly different from others. The lowest number of pupae was found in (1.33) Diazinon treated plot which was statistically similar to that of another micronutrient treated plot. The highest number of pupae (4.67) was found in Zn 6kg/ha treated plot which was not significantly different from that of untreated control and all other treated plots. At last observation was insignificant which might be due to hard soil and end of pupation period [33].

10. Yield of bitter gourd

The highest marketable yield (14.28 t/ha) was obtained from Mn 6kg/ha treated plot which was statistically similar to that of Mn 3kg/ha (13.43 t/ha) and Cu 6kg/ha (12.53 t/ha) treated plots (Table 10). The lowest marketable yield (6.55 t/ha) was observed from untreated control plot which was significantly different from those of other treated plots. The highest total yield (19.03 t/ha) was observed from Mn 6kg/ha treated plot which was statistically identical to that of Mn 3kg/ha (17.91 t/ha) and Cu 6kg/ha (16.70 t/ha) treated plots. The lowest total yield (8.74 t/ha) was observed in untreated control plot which was significantly different from all other treated plots. Total yield ranges from 19.03 to 8.74 t/ha. Management of fruit fly using Mn with two doses and Cu 6kg/ha treated plots gave increased yield of bitter gourd. There is not available literature on the effect of micronutrient on the yield of bittergourd. Manganese is mainly absorbed by plants in the form of Mn++. Manganese may act as a substitute of magnesium by activating certain phosphate-transferring enzymes, which in turn affect many metabolic processes [28]. The maximum yield produced by Mn application might be for suppressing the fruit fly infestation and fruit fly does not develop resistance against Mn 6kg/ha treated plots [32,34]. On the other hand, the repeated application of B might be developed fruit fly resistant resulting optimal level of fruit fly suppression. But Ho [35 found higher yield in boron treated plots. But in the present study the Mn treated plot gave better performance.

Table 10: Effect of selected micronutrients on the yield of bitter gourd (t/ha)

Treatment with doses	Marketable yield	Total yield	Increased yield over control
Mn(3kg/ha)	13.43ab	17.91ab	51.20
Mn(6kg/ha)	14.28a	19.03a	54.07
Zn(6kg/ha)	10.31cde	13.76def	36.48
Zn(12kg/ha)	11.08cde	14.78cdef	40.86
B(2kg/ha)	9.81de	13.07ef	33.13
B(4kg/ha)	9.50e	12.66f	30.96
Cu(6kg/ha)	12.53abc	16.70abc	47.66
Cu(12kg/ha)	11.87bcd	15.83bcd	44.79
Diazinon(16.8kg/ha)	11.86bcd	15.81bcde	44.72
Control	6.55f	8.74g	
Significance level	*	*	
LSD value	2.34	2.75	
CV	7.87	7.56	

* Means are separated by LSD at 5 percent level of significance

The yield increase over control in treated plot of bitter gourd ranged from 30.96 – 54.07%. The highest increased yield over control (54.07%) was found in Mn 6kg/ha treated plot followed by Mn 3kg/ha (51.20%) treated plot. The lowest increased yield (30.96%) over control was found in B 4kg/ha treated plot followed by B 2kg/ha treated plot (Table 10).

11. Micronutrients (ppm) in the soil

The levels of Mn, Zn, B and Cu in the soil of the test plots before their application were 3.4 ppm, 3.02 ppm, 0.96 ppm and 2.7 ppm, respectively. At the end of harvest, the levels of Mn, Zn, B and Cu in the soil of the same plots treated with those elements were 5.99 ppm, 4.56 ppm, 1.23 ppm and 3.5 ppm, respectively (Table 11). It was observed from the results that all the elements which were applied in the soil remain in the soil after partial consumption by plants of bitter gourd. It was also found that the levels of all the elements in soil at the end of harvest increased as compared to the levels before their application. The range of the levels of increase of elements was 21.95 – 43.23%. The highest percent of increase was found in case of Mn (43.23%) and the lowest percent of increase was found in B (21.95%).

Total soil Zn ranges from 10 to 300 mg/kg and soil Mn concentration ranged from 20 to 3000 mg/kg [36]. Schimid [37] found that increasing level of copper competitively reduced the zinc absorption by barley root. This might be one of the reasons of copper giving better result than zinc. Soil contains a total 1 to 50 mg of copper/kg and 20 to 50 mg/kg B an average. Residual copper usually constitutes about 50% of total copper. This is the smaller proportion than for some other such as zinc, phosphorus and potassium where a major portion of nutrients may be in the residual fraction [38]. In this study it was observed that Mn has highest concentration than Zn, Cu and B. Manganese at higher doses gave good result and Mn at lower doses induce higher infestation. Manganese at higher doses might be accumulate at higher rate and might suppress fruit fly attack simultaneously resulted maximum yield.

Table 11: Micronutrients (ppm) in the soil

Treatment	Cu	Mn	B	Zn
Before micronutrients application in the field	2.7	3.40	0.96	3.02
After micronutrients application at the end of harvesting	3.5	5.99	1.23	4.56
% Increased micronutrients level	22.85	43.23	21.95	33.77

Conclusion

The following conclusions are drawn from the findings

- Micronutrients Zn has the positive effect on earlier flower initiation and total number of flowers in bitter gourd.
- Fruit infestation of bitter gourd by number and weight was lower in Mn 3 kg/ha, Mn 6 kg/ha and Cu treated plots than all other treatments.
- Overall percent of damaged portion of infested fruits of bitter gourd was lower in the plots treated with Mn and Cu than other plots.
- The lower numbers of pupae of fruit fly were found in the soil of Mn, Cu and Diazinon treated plots.
- The overall yield of bitter gourd was higher in the Mn and Cu treated plots than other treated plots.
- The highest percent reduction of yield over control was found in Mn 3 kg/ha, Mn 6 kg/ha and Cu 12kg/ha treated plots (51.20, 54.07 and 47.66%).
- The highest percent of Mn was found to remain in the soil after harvest.
- Mn and Cu might be used as a component of Integrated Pest Management of fruit fly attacking bitter gourd.

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