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# Jasmonic acid and biorationals induced resistance against two spotted spider mite, *Tetranychus urticae* Koch in Okra

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**Abstract**
Okra or bhendi (*Abelmoschus esculentus* (L.) Moench is an important nutritious vegetable grown in tropical and sub tropical countries of the world. The production of okra is challenged by the infestation of two spotted spider mite, *Tetranychus urticae.* A study was conducted to assess the effect of various organic and inorganic fertilizers, jasmonic acid, bio control agent *Pseudomonas fluorescens* and acaricide on population of *T. urticae* on the moderately resistant okra hybrid COBhH 1. TNAU RDF with propargite 2 ml/lit was highly effective and registered the highest per cent reduction of mites (90.45). Of the treatments with jasmonic acid, organic amendments with jasmonic acid registered a population reduction of 78.65 per cent and with a fruit yield of 368.33 g/plant. The effect of these treatments on the population of predatory mites revealed reduction in predatory mite population in TNAU RDF + propargite 2 ml/litre, while the other treatments showed improvement in their population. Jasmonic acid and the octadecanoid pathway are involved in induction of both direct and indirect plant responses to herbivore feeding damage. Foliar jasmonic acid application increased levels of polyphenol oxidase, an oxidative enzyme implicated in resistance against several insect herbivores. Elicitors such as jasmonic acid may be valuable pest management tools, especially when there are high densities of herbivores that can reduce yield.

**Keywords:** Two spotted spider mite, bio-efficacy, acaricides, Jasmonic acid, biotic stress induced resistance

## Introduction

Among several vegetable crops cultivated in India, okra or bhendi (*Abelmoschus esculentus* (L.) Moench) which belongs to the family Malvaceae is one of the world's oldest, traditional cultivated crops and an important source of vitamins (A, B and C), protein, minerals, phospholipids and an excellent supplement of iodine and calcium. Okra can be cultivated throughout the year and is one of the best adopted vegetables in the tropical condition with the added advantages of early bearing and extended period of harvest coupled with short duration. The production and yield of this highly valued crop is quite often hampered by various insect species and a few mite species from early stage to maturity. Besides insect pests, several species of mites belonging to the genus *Tetranychus* (Gupta, 1985; Srinivasa and Sugeetha, 1999) [35, 36] cause a loss in the yield of okra fruits ranging from 7 to 48 per cent. Among the mites attacking this crop, the two spotted spider mite, *Tetranychus urticae* Koch has been identified as one of the most serious pests that causes extensive damage. *T. urticae* is a generalist feeder and the most polyphagous species on more than 1,100 host plants belonging to more than 140 families, including those that are known to produce toxic compounds [Gebric, 2011; Van leeuweek *et al*, 2012]. T. urticae is responsible for causing loss of foliage of the crop resulting in reduction in yield of fruits ranging from 20-45% depending upon cropping season and agroclimatic conditions (Jayabal *et al.*, 2017) [37].

Though several pest control methods are employed to combat the menace of this pest, acaricides are being the primary control tactic adopted by many farmers. But, the continuous use of acaricides leads to the development of resistance, destruction of natural enemies, environmental pollution and residue contamination in the produce. Development of resistance to a wide range of acaricides and insecticides has been documented throughout the world.

These acaricides that target two spotted spider mite also kill beneficial parasitoids and predators (Simmons and Jackson, 2000) [40]. Therefore, better alternative would be utilization of induced resistance in the crop along with the available bio rationales to combat the mite infestation and therefore increase the yield. Elicitors are a practical way to induce plant responses because they can be patented, manufactured, and applied to large numbers of plants by conventional spray technologies. To use induced responses as an effective pest management tool we must evaluate the effects of induced responses on plant performance and yield in an agricultural setting. Manipulating plant induced responses will only be an effective tool. Jasmonic acid is found in many plant species and is involved in regulating diverse plant functions, including plant resistance and senescence (Creelman and Mullet 1997) [40, 41]. Jasmonic acid is produced by the plant after caterpillar damage and results in increased production of compounds involved in resistance (Constabel *et al.*, 1995, Thaler *et al.*, 1999) [1, 2]. In tomatoes, application of jasmonic acid results in induction of proteinase inhibitors and polyphenol oxidase and in a decrease in the preference, performance, and abundance of many common herbivores in the Þeld, including *Frankliniella occidentalis* Pergrande (thrips), *Spodoptera exigua* and *Trichoplusia ni* Hu¨bner (noctuid caterpillars), *Epitrix hirtipennis* Melsheimer (ßea beetles), and *Macrosiphum euphorbiae* Thomas, and *Myzus persicae* Sulzer (aphids) (Thaler, Stout, Karban, and Duffey 1999 [2].

## Methodology

Field experiment were conducted to evaluate influence of jasmonic acid, organic amendments and bio rationales and their combinations on the two spotted mite damage on okra the performance of COBhH1.

The experiment was conducted in Randomized Block Design with 3 replication and treatments as mentioned

| | |
|---|---|
| $T_1$- | TNAU package of recommended fertilizers |
| $T_2$- | TNAU package of practices + propargite 2 ml /l. |
| $T_3$- | TNAU package of practices + Jasmonic Acid (1.0 mM) |
| $T_4$- | Jasmonic Acid (1.0 mM) |
| $T_5$- | Organic amendments (FYM + Vermicompost + *Pseudomonas fluroscens* (2.5 kg/ha) |
| $T_6$- | Organic amendments + Jasmonic Acid (1.0 mM) |
| $T_7$- | Control |

The treatments were imposed when the population of mites was noticed in the plants causing damage. Pretreatment count and the post treatment counts were recorded on 3,7,10 and 14 days after first and second application of treatment. The mite population was assessed in the top, middle and bottom canopy leaves of treated plants. From each leaf, the mites were counted in one $cm^2$ area. Population of mites from 10 plants / plot @ 3 leaves and 2 $cm^2$ area / leaf Predatory mite / leaf @ 3 leaves / plant, totally 10 plants / plot and Fruit yield (t/ha) was assessed.

The mite population were subjected to square root (X + 0.5) transformation, while the percentage data were subjected to arcsine transformation. The data obtained experiments were subjected to analysis using AGRES and the mean values separation was compared by LSD either at 5 or 1 per cent level (Least Significant Difference).

## Results and Discussion

The results of the experiment elucidated effectiveness of jasmonic acid, insecticides and biorationals on the control of mites. Among the treatments, TNAU RDF(Recommended Dose of Fertilizers) + propargite 2 ml/lit was found to be highly effective and registered the highest per cent reduction of mites (90.45) compared to other treatments (Fig.22) and also registered the higher yield of okra. Among the treatments that included jasmonic acid, organic amendments + jasmonic acid registered a population reduction of 78.65 per cent with a yield of 368.33 g/plant. TNAU RDF was the least effective and could effect only 46.60 per cent reduction of population over control and registered 51.90 per cent increase in yield over the control plants. TNAU RDF + jasmonic acid and jasmonic acid alone, followed the organic amendments and jasmonic acid treatment registering 70.54 and 73.23 per cent reduction of mites from control after two rounds of treatments and had 66.22 and 42.42 per cent increase of yield over control, respectively.

The findings clearly indicate the acaricidal properties of the propargite and the results are in accordance with earlier reports of Rai and Singh (2008) who reported that propargite was found to be effective against *T. urticae* and caused 82.66 per cent reduction from control. Bio efficacy evaluation by Jeyarani *et al*. (2007) [4] also revealed that propargite 850 g a.i. $ha^{-1}$ recorded 70.13 per cent reduction of chilli yellow mite with the maximum fruit yield.. The reduction in the mite population might be due to the quick knock down effect of the chemical and since, propargite is an organic sulfite, chemical that inhibits oxidative phosphorylation and disrupts mitochondrial ATPase, which results in inhibition of ATP formation that causes interruption of normal mite metabolism and interferes with respiration. Moreover, propargite is a non-systemic acaricide with predominantly contact action and also with some additional action by inhalation. This chemical is known for its action particularly on the motile stages (nymps and adults) of mites by inhibition of energy production.

Reasons for the lower reduction of mite in the TNAU RDF treatment might be due to the increase in the nitrogen content of the plant, scrutiny of the data revealed that quantity of the nitrogen applied to the soil had a positive influence on the mite population 10 days after treatment. Although the population reduction was less compared to other treatments, the yield was comparably higher and this may probably due to the excessive vegetative growth observed at the applied level of NPK. Similar results were obtained by Ramaraju *et al*. (2007) [5] and Moore *et al*. (1991) [6] on coconut against eriophyid mite and Rajaram and Ramamurthy (2001) [7] on chillies against *Polyphagotaronemus latus*. It is well known fact that application of recommended dose of nutrients plays an important role in improving the vigour of the plants. The control of mites by the recommended dose of fertilizer may be due to the fact that potassium imparts resistance to the mites and also acts as an activator of numerous enzymes, enhances the metabolic processes to reduce the mite incidence.

The superiority of the organic amendments and jasmonic acids are in accordance with results of Murugan (2003) who reported that application of jasmonic acid at 1.00 mM concentration with *P. fluorescens* applied in soil recorded reduced number of sucking pests compared to control on okra. *P. fluorescens* applied to soil as well as foliar spray on tomato recorded significantly lower pests than control and higher than with jasmonic acid (Murugan, 2003). Plant growth promoting rhizobacteria like *P. fluorescens* would induce the plant to protect systematically following induction with an inducing agent (Kloepper *et al*., 1992) [8]. *Pseudomonas* spp. induced several defense genes in the colonized plant that encode pathogen related proteins like chitinase, β-1, 3 glucanase, and polyphenol oxidase, chalcene synthase and phenylalanine ammonia lyase and induced accumulation of phenolics, callose, lignin and phytoalexins (Hammerschmidt *et al.*, 1982; Dalisay and Kuc, 1995; Xue *et al*., 1998) [9, 10, 11]. Tomczyk (2002) [13] reported enhanced changes in total phenols and cucurbitacin content in the leaves of cucumber plants growing in the presence of plant growth promoting rhizobacteria in root system of healthy plants and plants infested with two spotted spider mite.

Arancon *et al*. (2007) [12] found the application of vermicompost reduced the degree of development of two spotted spider mite damage in brinjal plants. The leaf area, height and shoot dry weight of the egg plants increased significantly in response to decreased damage by spider mites. Asami *et al*. (2003) [14] reported that total amounts of phenolic substances were much higher in strawberries and corn grown organically than in those grown with inorganic fertilizers.

Field treatments with vermicomposts decreased the occurrence of leaf miner, *Aproaerema modicella* Deventer on groundnuts (Ramesh, 2000) [15]. Rao *et al*. (2001) [16] and Rao (2002) [17] reported considerable decreases in populations, of jassids, aphids, coccinellid bettles and spider mites on groundnuts grown in soils amended with vermicompost, neem cake or farmyard manure, compared to those grown in soils amended with inorganic fertilizers (Rao *et al*.,2001 ;Rao, 2002) [16, 17]

Two of the mechanisms for decreasing pest attacks that have been suggested by researchers are based on either differential availability of mineral nutrients to plants or on changes in the balance of available nutrient elements, that could affect aspects of plant morphology and physiology in ways that could render plants more resistant to pest attacks (Patriquin *et al.*, 1995; Fox and Macauley, 1977; Prestidge and McNeill, 1983) [18, 20, 19]. Some of the changes in plant characteristics that are affected by organic or inorganic nutrition are their growth patterns such as the onset of senescence, thickness and degree of lignification of the epidermal cells, sugar concentrations in the apoplasts, amino-N in phloem sap, and levels of secondary plant compounds (Patriquin *et al*., 1995) [18]. The substitution rates of 20 and 40 per cent vermicomposts suppressed populations of both aphids and mealy bugs on peppers, and mealy bugs on tomatoes significantly (Arancon *et al*., 2005) [12].

Pest suppressing activity of neem cake may be attributed primarily to certain phenolic compounds released during decomposition (Alam *et al*., 1979) [21] apart from stimulatory effect on root growth which helped profuse growth of roots to absorb nutrients easily. Neem cake contains 2 per cent of terpenoids mainly azadirachtin which is responsible for the antifeedant, antiovipositional, growth disruption, fecundity and fitness reducing properties on insects.

In case of jasmonic acid treatments per cent reduction in mite population was more than 70 per cent coupled with increase in yield. Thaler *et al.* (1999 and 2001) [2, 3] reported that the common herbivores on tomato were reduced in abundance by jasmonate – mediated induction which included both sucking as well as chewing pests that had different guilds. Herbivores of tomato plants, *viz., T. urticae* and *H. zea* (Stout *et al*., 1994, 1996; Stout and Duffey, 1996) [22, 23, 27] had been reported to be negatively affected by the induced response of jasmonic acid. In the field, Thaler *et al.* (1999) [2] found the plants treated with jasmonic acid had higher peak activites of both polyphenol oxidase and proteinase inhibitors compared to the control plants which might be the reason for the reduction in population of mites. Jasmonic acid stimulated activities of some enzymes are critical for the terpenoid volatile biosynthesis (Bouwmeester *et al*., 1999) [28]. In the present study, the application of jasmonic acid with organic ammendedments might have activated the octadeconoid pathway that inturn might have caused antixenosis and antibiosis, the basic action of exogeneously applied jasmonic acid.

**Effect of fertilizers, acaricide, jasmonic acid and organic amendments on the population of predatory mite**

The reduction in predatory mite population was noticed in TNAU RDF + propargite 2 ml/lit, while the other treatments showed an increase in their population. After two rounds of treatments, organic amendments + jasmonic acid recorded 30.78 per cent increase in the predatory mite population than the control followed by TNAU RDF + jasmonic acid (28.80%). Organic amendments and jasmonic acid when applied separately, they could effect a 22.70 and 19.66 per cent increase in the predatory mite population respectively, while TNAU RDF recorded 13.28 per cent increase in the predatory mite population over the control.

The findings reveal the toxic effect of acaricide on the predatory mite, while the organic amendments, fertilizers and jasmonic acid were not only safe to the predatory mite, but also increased their population in the field.. Spraying of acaricides like hexythiazox, fenpyroximate and abamectin were toxic to predatory mite *P. persimilis* (Nadimi *et al*., 2008) [29] Milbemectin and fenazaquin were very toxic to adult females and immatures of *P. persimilis* (Yano *et a*l.,, 2002) [30]. The increase in predatory mite population in other may be due to the attraction of predatory mite through the herbivore induced volatile. Indirect plant defense through info chemicals involves the emission of herbivore – induced plant volatiles that attract the enemies of herbivores (Dicke *et al*., 1990) [31]. Odour produced by *T. urticae* infested kidney bean plant attracts predatory mite *Amblyseius womersleyi* (Schicha) (Maeda *et al*., 1999) [32] that application of JA to lima bean induced a volatile blend that is similar, but not identical to that emitted by spider mite infested plants. The blends of volatiles originate from lipoxygenase pathway, shikimic acid pathway and isopropenoid pathway and the compounds of these pathways are known to attract *P. persimilis*. It was found that treatment of lima bean plants with a 1 mM JA solution resulted in significant attraction of predatory mites (Dicke *et al*., 1999) [31].

Murugan (2003) reported predators *viz*., spider, coccinellid and predatory mirids were predominant in *P. fluorescens* treated tomato plots than the check. *Pseudomonas fluorescens* treated plots had more number of spiders than to the tune of 4-7 per ten hills. They further noticed that in all the instances, the untreated plots also registered less natural enemies than pseudomonas treated plants. The increase in natural enemy population might have associated with some host bacteria based pathway (octadenoid pathway) leading

to the production of volatile compounds. The activation of octadenoid pathway and increased amount of volatile substance has been reported earlier by Bell and Mullet (1993) [40]. The increase in predator activity in the organic amendments treated plots is supported by Giraddi (2007) [33] who found application of organics (vermicompost, neemcake and vermin wash) did not affect the predators *Menochilus sexmaculatus* (F.) and *Chrysoperla carnea* (Stephens) and their population was comparable to the predator density in untreated control.
Jasmonic acid and the octadecanoid pathway are involved in induction of both direct and indirect plant responses to herbivore feeding damage. This study showed that both the herbivorous spider mite, *T. urticae*, and its predator, *P. persimilis*, prefer spider-mite-infested plants to uninfested plants, whereas only the predators also prefer JA-induced plants to uninduced control plants. A clear correlation was found between spider mite density and the degree of attraction of predatory mites. Not only is the emission of plant volatiles affected by spider mite densities, the duration of the infestation affects the quantity and quality of the released plant volatiles as well (Maeda and Takabayashi, 2001) [32].

**Table 1.** Effect of fertilizers, acaricide, jasmonic acid and organic amendments on *T. urticae* population in COBhH-1 okra

| Treatments | I Round (population Nos. / cm$^2$ leaf area) | | | | | Mean | % reduction |
|---|---|---|---|---|---|---|---|
| | PTC | 3 DAT | 7 DAT | 10 DAT | 14 DAT | | |
| TNAU RDF | 21.02 (4.58) | 20.33 (4.50) | 16.87 (4.10) | 19.19 (4.38) | 23.12 (4.80) | 19.88$^g$ (4.47) | 39.20 |
| TNAU RDF + propargite 2 ml / lit. | 22.77 (4.72 | 8.94 (2.98) | 2.07 (1.43) | 2.84 (1.67) | 5.09 (2.25) | 4.73$^c$ (2.61) | 85.52 |
| TNAU RDF + Jasmonic Acid | 25.80 (5.05 | 22.62 (4.75) | 18.67 (4.32) | 13.67 (3.69) | 10.56 (3.24) | 16.38$^f$ (4.21) | 49.91 |
| Jasmonic Acid | 22.64 (4.74 | 20.35 (4.51 | 17.93 (4.23) | 10.76 (3.27) | 7.59 (2.74) | 14.16$^e$ (3.90) | 56.70 |
| Organic amendments | 24.53 (4.94 | 21.82 (4.67) | 19.96 (4.46) | 17.01 (4.12) | 15.92 (3.98) | 18.68$^g$ (4.43) | 42.87 |
| Organic amendments + Jasmonic Acid | 22.19 (4.70 | 19.76 (4.44) | 16.09 (4.01) | 10.27 (3.20) | 5.57 (2.35) | 12.92$^e$ (3.74) | 60.47 |
| Control | 23.03 (4.78) | 27.42 (5.23) | 30.98 (5.56) | 34.39 (5.86) | 37.97 (6.16) | 32.69$^h$ (5.52) | - |
| Mean | (4.79)$^g$ | (4.44)$^f$ | (4.01)$^e$ | (3.74)$^d$ | (3.65)$^d$ | - | - |

**SED CD (0.05) CD (0.01)**
Spray 0.0310 0.0618 0.0810
Days 0.0490 0.0970 0.1281
Treatment 0.0580 0.1148 0.1516
Spray X Days 0.0694 0.1372 0.1812
Days X Treatment 0.1298 0.2567 0.3391
Spray X Treatment 0.0821 0.1623 0.2144
Spray X Days X Treatment 0.1836 0.3631 0.4795
Figures in the parentheses are √ X + 0.5 transformed values
Means followed by the common letter (s) are not significantly different at 5 % level by LSD.

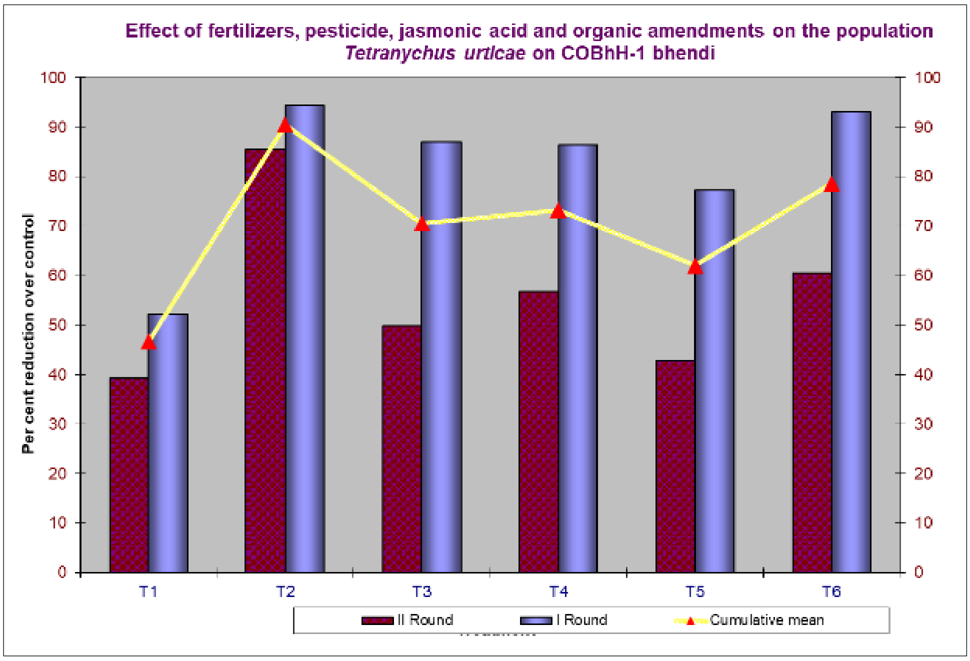


**Fig 1:** Effect of fertilizers, pesticide, jasmonic acid and organic amendments on the population Tetranychus urticae on COBhH-1 bhendi

**Table 2:** Effect of fertilizers, acaricide, jasmonic acid and organic amendments on *T. urticae* population in COBhH1 – II Round

| Treatments | II Round (population Nos. / cm² leaf area) | | | | | Mean | % reduction |
|---|---|---|---|---|---|---|---|
| | PTC | 3 DAT | 7 DAT | 10 DAT | 14 DAT | | |
| TNAU RDF | 23.12 (4.80) | 20.66 (4.54) | 17.32 (4.15) | 18.99 (4.35) | 21.42 (4.62) | 19.60[g] (4.49) | 52.26 |
| TNAU RDF + propargite 2 ml /l. | 5.09 (2.25) | 2.14 (1.45) | 1.63 (1.26) | 1.95 (1.38) | 3.51 (1.87) | 2.31[a] (1.64) | 94.37 |
| TNAU RDF + Jasmonic Acid | 10.56 (3.24) | 8.65 (2.93) | 6.36 (2.52) | 3.95 (1.99) | 2.43 (1.56) | 5.35[b] (2.45) | 86.97 |
| Jasmonic Acid | 7.59 (2.74) | 7.33 (2.70) | 4.92 (2.21) | 5.36 (2.31) | 4.73 (2.17) | 5.59[b] (2.43) | 86.39 |
| Organic amendments | 15.92 (3.98) | 12.70 (3.56) | 9.98 (3.16) | 7.53 (2.74) | 6.98 (2.61) | 9.30[d] (3.21) | 77.35 |
| Organic amendments + Jasmonic Acid | 5.57 (2.35) | 4.87 (2.2) | 3.15 (1.77) | 1.86 (1.36) | 1.41 (1.18) | 2.82[a] (1.77) | 93.12 |
| Control | 37.97 (6.16) | 41.45 (6.44) | 42.21 (6.49) | 38.55a (6.20) | 41.98 (6.48) | 41.05[i] (6.35) | - |
| Mean | (3.65)[d] | (3.40)[c] | (3.08)[b] | (2.91)[a] | (2.93)[a] | (3.66) | - |

**Table 3:** Effect of fertilizers, acaricide, jasmonic acid and organic amendments on *T. urticae* population and yield of COBhH1

| Treatments | Mean mite population (nos/cm² leaf area) | | | % Population reduction over control | Yield (g/plant) | % Yield increase over control |
|---|---|---|---|---|---|---|
| | I spray | II spray | Pooled mean | | | |
| TNAU RDF | 19.88 | 19.60 | 19.74[f] | 46.60 | 263.33[c] | 51.90 |
| TNAU RDF + propargite 2 ml / lit. | 4.73 | 2.31 | 3.52[a] | 90.45 | 425.00[a] | 70.20 |
| TNAU RDF + Jasmonic Acid | 16.38 | 5.35 | 10.86[d] | 70.54 | 375.00[b] | 66.22 |
| Jasmonic Acid | 14.16 | 5.59 | 9.87[c] | 73.23 | 220.00[d] | 42.42 |
| Organic amendments | 18.68 | 9.30 | 13.99[e] | 62.05 | 246.67[c] | 48.65 |
| Organic amendments + Jasmonic Acid | 12.92 | 2.82 | 7.87[b] | 78.65 | 368.33[b] | 65.61 |
| Control | 32.69 | 41.05 | 36.87[g] | | 126.67[e] | |

Organic amendments - FYM + Vermicompost + *Pseudomonas fluorescens*
Figures in the parentheses are √ X + 0.5 transformed values
Means followed by the common letter (s) are not significantly at 5 % level by LSD.

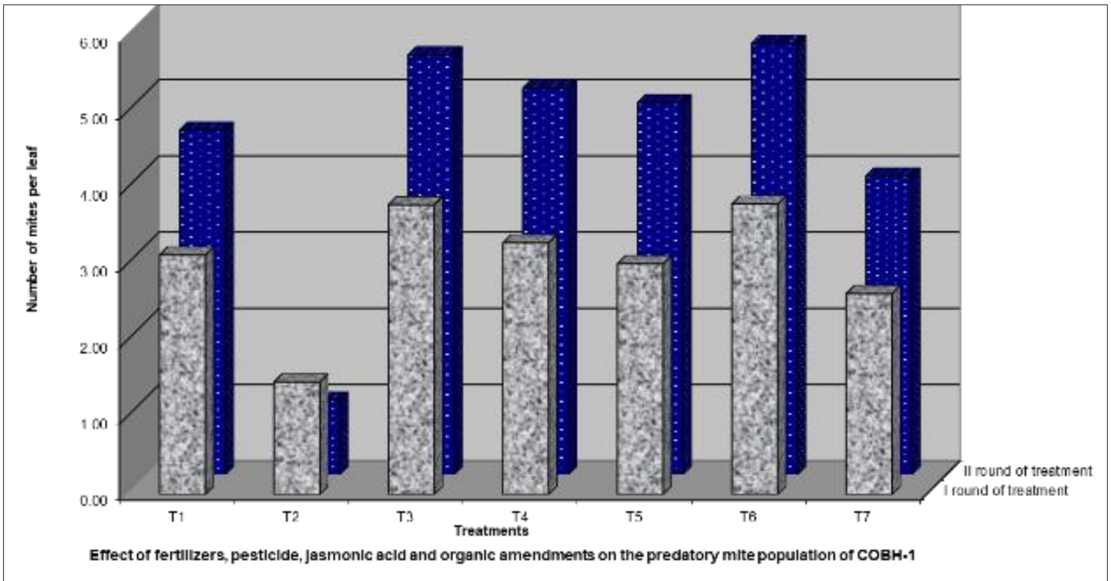


**Fig 1:** Effect of fertilizers, pesticide, jasmonic acid and organic amendments on the predatory mite population of COBH-1

## Conclusion

The findings indicate that organic amendments and jasmonic acid treatments significantly reduced the damage caused by spider mites and increased eggplant weight. Organic amendments, such as vermicomposts and neem cake, were found to suppress pest populations by enhancing plant resistance, potentially through changes in nutrient availability and plant morphology. Jasmonic acid, when applied with organic amendments, triggered an induced resistance response, effectively reducing mite populations and improving yield. Additionally, jasmonic acid and organic treatments promoted the increase of predatory mite populations, highlighting their role in fostering natural pest control. Overall, the integration of jasmonic acid and organic amendments presents a promising sustainable pest management strategy.

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