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Effect of Different Levels of Farmyard Manure (FYM) Integrated with Organic Modules on Yield, Quality and Pest Incidence of Okra (*Abelmoschus esculentus* L. Moench)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The study was conducted during late *Kharif* season during 2021-22 and 2022-23 at administrative office (PGIHS), Sri Konda Laxman Telangana State Horticultural University, Mulugu, Telangana, India. The experiment was laid out in contrast factorial randomized block design (CFRBD) with two factors *i.e.,* factor-1 consists of three levels of FYM and factor-2 consists of three organic modules and separate control (100% RDF) plot was grown and replicated thrice. The pooled results indicated that, control treatment (100 % RDF-100:50:50 kg NPK/ha) reported highest number of fruits per plant (19.05), highest fruit weight (14.72 g), maximum fruit yield per plant (0.28 kg), maximum fruit yield per hectare (9.52 t/ha) over the other treatments. L_1M_1 (FYM equivalent to 100 % RDN + organic module-1) registered minimum crude fibre content (7.10%), and maximum chlorophyll content in fresh fruit (1.19 mg/100g). While, minimum mean percent of fruit infestation (6.28%) was reported with control (100% RDF-100:50:50kg NPK/ha + emamectin benzoate 5%SG @ 70 g/200 lit) and lowest mean population of jassid per leaf (1.08/leaf), was recorded with control (100 % RDF-100:50:50 kg NPK/ha + imidacloprid 17.8 SL @ 100 ml/acre).

Keywords: Okra; organic farming; biological control; biopesticides and FYM.

1. INTRODUCTION

Okra, scientifically known as *Abelmoschus esculentus* (L.) Moench, is a significant vegetable commonly referred to as lady's finger and locally named bhindi in India. It has a chromosome number of 2n=130 and originated from tropical and subtropical regions of Africa. Okra is prized for its tender fruits and is categorized as a crucial vegetable crop for both rainy and summer seasons, belonging to the Malvaceae family. Okra is recognized for its high iodine content and its effectiveness in treating goiter. The fruit is beneficial for managing genito-urinary disorders, spermetorrhoea, and chronic dysentery. Dried okra fruit contains approximately 13-22% edible oil and 20-24% protein, suitable for use as refined edible oil [1]. Research indicates that 100 grams of fresh okra pods contain 89.6% moisture, along with 103 mg of potassium, 90 mg of calcium, 43 mg of magnesium, 56 mg of phosphorus, 18 mg of vitamin C, and trace metals such as iron and aluminum [2]. India holds the title of the world's largest producer of okra. In the year 2020-21, the total area dedicated to okra cultivation in India was 513,000 hectares, yielding a production of 6,466,000 metric tons of green fruits, with a crop productivity of 11.63 tons per hectare [3]. Okra contributes 4.9% of the total vegetable cultivation area and 3.3% of the production. West Bengal leads in both the area under cultivation and production of okra, while Jammu and Kashmir highest in productivity. Other major okra-producing states include Andhra Pradesh, Bihar, Odisha, Gujarat, Jharkhand, Telangana, Karnataka, and Tamil Nadu.

Successful cultivation of okra hinges on several factors, with the careful application of fertilizers being critical. Overuse of fertilizers and chemical pesticides not only degrades soil health and the quality of produce but also renders it unsuitable for export due to contamination concerns. Consumers are concerned about the vegetables they eat. Both the international and domestic communities are becoming more and more conscious on issues like residues of poisonous agrochemicals in vegetables and their associated health and environmental hazards. The current global scenario firmly emphasizes the need to adopt eco-friendly practices for sustainable food production that paves a path for organic agriculture [4,5].

In the foreseeable future, utilizing organic manures to fulfill crop nutrient needs will be indispensable for sustainable agriculture. Organic manures are known to enhance soil physical, chemical, and biological properties, while preserving its moisture retention capacity. This leads to enhanced crop production and maintenance of crop quality [6]. Moreover, organic manure increases cation exchange capacity, improves water holding capacity, and enhances soil phosphate availability. It also boosts fertilizer efficiency and promotes soil microbial populations, thereby reducing nitrogen losses through gradual nutrient release [7]. The biological control of insect pests using various entomopathogenic microorganisms is increasingly valued for their specificity to targets, self-sustaining nature, and environmental safety. Entomopathogenic fungi (EPF) such as *Beauveria bassiana*, *Metarhizium anisopliae*, and *Lecanicillium lecanii* have demonstrated effective pest control capabilities over decades. There have been no reports of resistance developing against these EPF so far. Compared to synthetic pesticides, bio-pesticides offer a safer and more sustainable approach to insect pest management [8]. Botanical pesticides like neem oil are also recognized as eco-friendly options for controlling pests such as jassids [9,10]. Neem based pesticides exhibit antifeedant, repellant, and toxic properties against insect pests [11]. The primary active ingredient in neem oil, azadirachtin, disrupts the synthesis and release of molting hormones (ecdysteroids) from the prothoracic gland, leading to incomplete molting in immature insects and sterility in adult females [12]. Similarly, spores of entomopathogenic fungi germinate on the integument of insects and secrete enzymes like chitinase, protease, and lipase, which degrade the insects' cuticle. This aids in the penetration of the fungal body into the insect's hemocoel, ultimately causing its death [13]. The aim of this experiment is to evaluate the impact of varying levels of farmyard manure (FYM), in combination with different organic modules, on the yield, quality, and pest incidence of okra (*Abelmoschus esculentus* L. Moench). This study seeks to determine the optimal FYM levels and organic module integrations that enhance okra productivity and quality while minimizing pest infestations. Through this, the experiment aims to provide sustainable agricultural practices that improve crop performance and reduce reliance on chemical inputs.

2. MATERIAL AND METHODS

The present investigation was conducted during late *Kharif* season during 2021-22 and 2022-23 at administrative office (PGIHS), Sri Konda Laxman Telangana State Horticultural University, Mulugu, Telangana. The experimental site comes under sub-tropical zone and is situated at a latitude of 17°43’02’’ N and a longitude of 78°37’34’’ E and altitude of 595 m above MSL. The research work was conducted in the Contrast Factorial Randomized Block Design with three replications. Factor-1 consists of three levels of FYM, calculated based on recommended dosage of Nitrogen and factor-2 consists of three organic modules and separate control (100% RDF) plot was grown.

2.1 Treatment Details

Factor 1: Farmyard Manure

L_1: FYM equivalent to 100% RDN
L_2: FYM equivalent to 75% RDN
L_3: FYM equivalent to 50% RDN

Based on the recommended dosage of fertilizers (RDF), farmyard manure is applied in different levels taking ‘N’ into criteria, RDF of okra: 100:50:50 kg/ha

Factor 2: Organic modules

Organic Module-1 (M_1):

- Application of *Trichoderma viride* @ 5kg/ha enriched in farmyard manure and neemcake @ 250 kg/ha and incorporated into the soil at the time of last ploughing.
- Seed treatment with *Trichoderma viride* @ 4g/kg seed.
- Spraying of 3 % panchagavya solution and 5 % neem oil at every 10 days interval up to the last harvest.
- Spraying of *Beauveria bassiana* @ 5g/liter and *Bacillus thuringiensis* @ 1kg/ha at every 10 days interval starting from flower initiation.

Organic Module-2 (M_2)

- Application of *Pseudomonas fluorescens* @ 5.0 kg/ha enriched in farmyard manure and neemcake @ 250 kg/ha and incorporated into the soil at the time of last ploughing.
- Seed treatment with *Bacillus macerans* @ 3% w/w.
- Spraying of 10 % vermiwash solution and Neem Seed Kernel Extract (NSKE) @ 5 % at every 10 days interval up to the last harvest.
- Spraying of *Metarhizium anisopliae* @ 5g/liter and NPV @ 250 LE/ha at every 10 days interval starting from flower initiation.

Organic Module-3 (M_3)

- Application of Vesicular Arbuscular Mycorrhizae @ 10kg/ha enriched in farmyard manure and neem cake @ 250 kg/ha incorporated into the soil at the time of last ploughing.
- Seed treatment with beejamrit @ 10 %
- Spraying of 10 per cent jeevamruth solution and neemastra 5 % at every 10 days up to the last harvest.
- Spraying of *Lecanicillium lecani* @ 5g/liter and *Trichoderma* + *Pseudomonas spp.* @

5g/liter at every 10 days interval starting from flower initiation.

2.2 Treatment Combinations

T_1 (L_1M_1): Farmyard manure equivalent to 100% RDN + Organic module-1
T_2 (L_1M_2): Farmyard manure equivalent to 100% RDN + Organic module-2
T_3 (L_1M_3): Farmyard manure equivalent to 100% RDN+ Organic module-3
T_4 (L_2M_1): Farmyard manure equivalent to 75% RDN + Organic module-1
T_5 (L_2M_2): Farmyard manure equivalent to 75% RDN + Organic module-2
T_6 (L_2M_3): Farmyard manure equivalent to 75% RDN + Organic module-3
T_7 (L_3M_1): Farmyard manure equivalent to 50% RDN + Organic module-1
T_8 (L_3M_2): Farmyard manure equivalent to 50% RDN + Organic module-2
T_9 (L_3M_3): Farmyard manure equivalent to 50% RDN + Organic module-3

Note: A control plot (100:50:50 kg NPK/ha) was grown separately to compare the data, for management of okra shoot and fruit borer and jassids, emamectin benzoate 5% SG @ 70 g/200 lit and imidacloprid 17.8 SL @ 100 ml/acre was sprayed respectively.

Seeds (local variety) were sown at 45×45 cm spacing and plot size of 7.5 m X 5 m, light irrigation was given after sowing. The soil of the investigation field was clay sandy with good drainage and uniform texture with medium NPK status. Observations were recorded according to standard procedure on number of fruits per plant, fruit weight, fruit yield per plant, fruit yield per hectare, crude fibre content (%) [14], chlorophyll content (mg/100g) according to the methodology of Arnon [15], percent of fruit infestation (%) by okra shoot and fruit borer, average no. of jassids per leaf (recorded at every 10 days interval). The data on these parameters were subjected to statistical analysis to draw logical conclusions.

3. RESULTS AND DISCUSSION

3.1 Number of Fruits Per Plant

The data with respect to number of fruits per plant as influenced by different treatments are presented in the Table 1.

Pooled data of two years 2021-22 and 2022-23 indicated that application of different levels of FYM has significantly influenced the number of fruits per plant. Among the different levels of FYM, maximum number of fruits per plant (16.77) was registered in L_1 (FYM equivalent to 100% RDN) followed by L_2 (FYM equivalent to 75% RDN) (14.27) while, minimum number of fruits per plant (12.54) was reported in L_3 (FYM equivalent to 50% RDN).

There was significant difference among organic modules with respect to number of fruits per plant. The maximum number of fruits per plant (15.35) was recorded with M_1 (organic module-1) which was followed by M_3 (organic module-3) (14.65). Whereas, the minimum number of fruits per plant (13.58) was recorded with M_2 (organic module-2).

The interaction between different levels of FYM and organic modules on number of fruits per plant was found significant among the treatments, also significant difference between control and rest of the treatments was registered. Maximum number of fruits per plant (19.05) was observed with control (100 % RDF-100:50:50 kg NPK/ha) which was at par with L_1M_1 -FYM equivalent to 100% RDN + organic module-1 (18.15), followed by L_1M_3 (FYM equivalent to 100% RDN + organic module-3) (16.78) and the minimum number of fruits per plant (11.61) was recorded with L_3M_2 (FYM equivalent to 50% RDN + organic module-2).

The highest number of fruits per plant was observed with the control treatment (100% recommended dose of fertilizers - 100:50:50 kg NPK/ha) in both seasons. This outcome can be attributed to the increased application of fertilizers, which resulted in greater availability of nutrients in the soil. This, in turn, enhanced nutrient uptake, leading to improved synthesis of metabolites and their effective transport, thereby promoting better fruit formation [16]. Nitrogen, phosphorus, and potassium in their available inorganic forms potentially stimulate increased production and assimilation of carbohydrates, as noted by Bidari and Hebsur [17]. The enhanced supply of essential nutrients also boosted their availability, uptake, mobilization, and influx into plant tissues, thereby increasing both the number of flowers and fruits [18]. Similar findings have been reported previously in studies involving tomato by Nawaz et al. [19] and Hozhbryan [20].

3.2 Average Fruit Weight (g)

The data recorded with respect to average fruit weight as influenced by levels of FYM and organic modules are presented in Table 1.

Pooled data of two years 2021-22 and 2022-23 indicated that application of different levels of FYM has significantly influenced average fruit weight. Among the different levels of FYM, maximum fruit weight (13.39 g) was registered in L_1 (FYM equivalent to 100% RDN) followed by L_2 (FYM equivalent to 75% RDN) (12.34 g) while, minimum fruit weight (11.52 g) was reported in L_3 (FYM equivalent to 50% RDN).

Significant difference among organic modules upon fruit weight was reported. The maximum fruit weight (12.90 g) was recorded with M_1 (organic module-1) followed by M_3 (organic module-3) (12.61 g). Whereas, the minimum fruit weight (11.73 g) was recorded with M_2 (organic module-2).

The interaction between different levels of FYM and organic modules on fruit weight differed significantly among the treatments and also significant difference between control and rest of the treatments was registered. Control (100 % RDF-100:50:50 kg NPK/ha) treatment reported highest fruit weight (14.72 g) which was followed by L_1M_1 - FYM equivalent to 100% RDN + organic module-1 (14.28 g). Lowest fruit weight *i.e.,* 10.77 g was recorded in the treatment L_3M_2 (FYM equivalent to 50% RDN+ organic module-2).

The highest fruit weight was observed with the control treatment (100% recommended dose of fertilizers - 100:50:50 kg NPK/ha). A sufficient supply of nitrogen not only stimulates the synthesis of nutrients but also promotes their effective distribution to the plant's storage organs. Nitrogen's influence on stomatal conductance enhances the transport of photosynthetic materials, facilitating the production and movement of sugars and starches from source to sink within the plants [21]. This contributes to an increase in the average pod weight of okra. These findings align with previous studies by Ilupeju et al. [22] and Bake and Omar [23].

3.3 Fruit Yield Per Plant (Kg)

The data recorded with respect to fruit yield per plant as influenced by different levels of FYM and organic modules are presented in Table 1.

Pooled data of 2021-22 and 2022-23 indicated that application of different levels of FYM has found significant with respect to fruit yield per plant. Among the different levels of FYM, maximum fruit yield per plant (0.23 kg) was registered in L_1 (FYM equivalent to 100% RDN) followed by L_2 (FYM equivalent to 75% RDN) (0.18 kg) while, minimum fruit yield per plant (0.14 kg) was reported in L_3 (FYM equivalent to 50% RDN).

There was significant difference among organic modules upon fruit yield per plant. The highest fruit yield per plant (0.20 kg) was recorded with M_1 (organic module-1) followed by M_3 (organic module-3) (0.18 kg). Whereas, the lowest fruit yield per plant (0.17 kg) was recorded with M_2 (organic module-2).

The interaction effect between different levels of FYM and organic modules upon fruit yield per plant was found significant and also significant difference was reported between control and rest of the treatments. Control (100 % RDF-100:50:50 kg NPK/ha) treatment reported maximum fruit yield per plant (0.28 kg) which was followed by L_1M_1 (FYM equivalent to 100% RDN + organic module-1) (0.26 kg). Minimum fruit yield per plant *i.e.,* 0.13 kg was recorded in the treatment L_3M_2 (FYM equivalent to 50% RDN+ organic module-2).

3.4 Fruit Yield Per Hectare (t/ha)

The data with regard to effect of different levels of FYM and organic modules and their interaction on fruit yield per hectare is depicted in Table 2.

The perusal of pooled data revealed that application of different levels of FYM has significantly influenced the fruit yield per hectare. Among the different levels of FYM, maximum fruit yield per hectare (8.03 t/ha) was registered in L_1 (FYM equivalent to 100% RDN) followed by L_2 (FYM equivalent to 75% RDN) (6.57 t/ha) while minimum fruit yield per hectare (5.45 t/ha) was reported in L_3 (FYM equivalent to 50% RDN).

Organic modules on fruit yield per hectare differed significantly among treatments. Maximum fruit yield per hectare (7.06 t/ha) was recorded with M_1 (organic module-1) which was followed by M_3 (organic module-3) (6.22 t/ha). M_2 (Organic module-2) has registered lowest fruit yield per hectare (6.76 t/ha).

Table 1. Effect of different levels of farmyard manure (FYM) integrated with organic modules on number of fruits per plant, average fruit weight (g) and fruit yield per plant (Kg)

	Pooled data of 2021-22 and 2022-23											
FYM levels (L)	**Number of fruits per plant**				**Average fruit weight (g)**				**Fruit yield per plant (Kg)**			
	Organic modules (M)				**Organic modules (M)**				**Organic modules (M)**			
	M_1	**M_2**	**M_3**	**Mean**	**M_1**	**M_2**	**M_3**	**Mean**	**M_1**	**M_2**	**M_3**	**Mean**
L_1	18.15	15.38	16.78	16.77	14.28	12.48	13.40	13.39	0.26	0.21	0.23	0.23
L_2	14.65	13.75	14.41	14.27	12.61	11.94	12.46	12.34	0.19	0.17	0.18	0.18
L_3	13.25	11.61	12.76	12.54	11.80	10.77	11.98	11.52	0.15	0.13	0.15	0.14
Mean	15.35	13.58	14.65		12.90	11.73	12.61		0.20	0.17	0.18	
Control	19.05				14.72				0.28			
	L	**M**	**L X M**	**Control**	**L**	**M**	**L X M**	**Control**	**L**	**M**	**L X M**	**Control**
SEm±	0.05	0.05	0.16	0.16	0.03	0.03	0.08	0.08	0.001	0.001	0.002	0.002
LSD (5%)	0.16	0.16	0.48	0.90	0.08	0.08	0.26	0.34	0.002	0.002	0.006	0.007

The interaction between different levels of FYM and organic modules on fruit yield per hectare differ significantly, also significant difference between control and rest of the treatments was registered. Control (100 % RDF- 100:50:50 kg NPK/ha) recorded the maximum fruit yield per hectare (9.52 t/ha) which was followed by L_1M_1 (FYM equivalent to 100% RDN + organic module-1) (8.58 t/ha) while, the treatment L_3M_2 (FYM equivalent to 50% RDN + organic module-2) reported minimum fruit yield per hectare (5.09 t/ha).

The main objective of cultivation of a crop is to have maximum marketable yield for better returns. Fruit yield is the ultimate objective for which different trials are conducted

The primary goal of crop cultivation is to achieve maximum marketable yield for optimal returns. Fruit yield serves as the ultimate objective, driving various trials and experiments. The highest fruit yield per plant and per hectare was achieved under the control treatment (100% recommended dose of fertilizers - 100:50:50 kg NPK/ha). Plants that were taller with more branches exhibited an increased photosynthetic area, leading to greater production and improved translocation of assimilated nutrients from source to sink. This resulted in a higher accumulation of assimilates, contributing to increased fruit number and fruit weight, ultimately enhancing overall yield [24] Pavitradev et al., [25] Kaur et al., [26]. The higher yield observed with the 100% recommended dose of fertilizers (RDF) can be attributed to the adequate supply of essential nutrients in a balanced proportion, promoting robust plant growth and ensuring sufficient photosynthate supply for sink development. Additionally, the higher concentration of NPK (100% RDF) likely enhanced the availability of plant nutrients, thereby improving yield attributes [27]. Similar results have been reported in other crops such radish [28] and tomato [29].

3.5 Crude Fiber (%)

The data recorded with respect to crude fibre content (%) as influenced by different levels of FYM and organic modules are presented in Table 2.

Pooled data of both years 2021-22 and 2022-23 indicated that application of different levels of FYM has significantly influenced crude fibre content. Among the different levels of FYM, minimum crude fibre content (7.25%) was registered in L_1-FYM equivalent to 100% RDN followed by L_2-FYM equivalent to 75% RDN (8.48%) while, maximum crude fibre content (9.25%) was reported in L_3- FYM equivalent to 50% RDN.

Significant difference among organic modules with respect to crude fibre content was reported. The minimum crude fibre content (8.20%) was recorded with M_1 - organic module-1 followed by M_3- organic module-3 (8.33%). Whereas, the maximum crude fibre content (8.46%) was recorded with M_2 - organic module-2.

Interactions between levels of FYM and organic modules on crude fibre content did not differ significantly while, significant difference between control and rest of the treatments was registered. While, minimum crude fibre content (7.10%) was observed with L_1M_1 (FYM equivalent to 100 % RDN + organic module-1) followed by L_1M_3 (FYM equivalent to 100 % RDN + organic module-3) (7.27%) and control (100 % RDF-100:50:50 kg NPK/ha) recorded 8.72 % crude fibre content.

The lowest crude fiber content was observed with L_1M_1 (farmyard manure equivalent to 100% recommended dose of nitrogen (RDN) + organic module-1). This decrease in crude fiber content can be attributed to the increased succulence resulting from higher nitrogen application (Mani and Ramanathan, 1981). The use of organic manure (FYM equivalent to 100% RDN + organic module-1) exhibited a distinct advantage in enhancing fruit quality compared to inorganic fertilizers. This improvement is likely due to a balanced C ratio, which facilitates the availability of nitrogen and organic carbon, thereby enhancing produce quality. As the crop matures, there was an increase in crude fiber content, potentially due to reduced succulence caused by cell wall thickening and reduced nitrogen uptake as the crop advances [6]. Applying farmyard manure at 20 t/ha resulted in the lowest recorded crude fiber content in okra fruits (10.31%). Similarly, spraying panchagavya at 3% also minimized crude fiber content in okra [30,31]. These findings corroborate earlier studies by Ciba et al. [32] Amiry et al. [33] and Alam et al. [34] on okra.

3.6 Chlorophyll Content in Fresh Fruit (mg/100g)

The data with respect to chlorophyll content in fresh fruit (mg/100g) as influenced by levels of FYM and organic modules are presented in Table 2.

Table 2. Effect of different levels of farmyard manure (FYM) integrated with organic modules on fruit yield per hectare (t/ha), crude fibre (%) and chlorophyll (mg/100g)

Pooled data of 2021-22 and 2022-23												
FYM levels (L)	**Fruit yield per hectare (t/ha)**				**Crude fibre (%)**				**Chlorophyll (mg/100g)**			
	Organic modules (M)				**Organic modules (M)**				**Organic modules (M)**			
	M_1	**M_2**	**M_3**	**Mean**	**M_1**	**M_2**	**M_3**	**Mean**	**M_1**	**M_2**	**M_3**	**Mean**
L_1	8.58	7.47	8.03	8.03	7.10	7.39	7.27	7.25	1.19	1.07	1.15	1.13
L_2	7.01	6.11	6.59	6.57	8.38	8.59	8.46	8.48	0.93	0.81	0.86	0.87
L_3	5.60	5.09	5.65	5.45	9.11	9.41	9.25	9.25	0.75	0.61	0.71	0.69
Mean	7.06	6.22	6.76		8.20	8.46	8.33		0.95	0.83	0.90	
Control	9.52				8.72				0.98			
	L	**M**	**L X M**	**Control**	**L**	**M**	**L X M**	**Control**	**L**	**M**	**L X M**	**Control**
SEm±	0.02	0.02	0.06	0.06	0.02	0.02	0.04	0.04	0.004	0.004	0.011	0.011
LSD (5%)	0.06	0.06	0.16	0.24	0.04	0.04	NS	0.16	0.011	0.011	NS	0.043

Factor: 1
L_1: Farmyard manure equivalent to 100% RDN
L_2: Farmyard manure equivalent to 75% RDN
L_3: Farmyard manure equivalent to 50% RDN

Factor: 2
M_1: Organic Module-1
M_2: Organic Module-2
M_3: Organic Module-3

Control: 100% RDF

Pooled data of two seasons data indicated that application of different levels of FYM has significantly influenced chlorophyll content in fresh fruit. Among the different levels of FYM, maximum chlorophyll content in fresh fruit (1.13 mg/100g) was registered in L_1 - FYM equivalent to 100% RDN followed by L_2 - FYM equivalent to 75% RDN (0.87 mg/100g) while, minimum chlorophyll content in fresh fruit (0.69 mg/100g) was reported in L_3- FYM equivalent to 50% RDN.

There was significant difference among organic modules upon chlorophyll content in fresh fruit. The maximum chlorophyll content in fresh fruit (0.95 mg/100g) was recorded with M_1 - organic module-1 followed by M_3- organic module-3 (0.90 mg/100g). Whereas, the minimum chlorophyll content in fresh fruit (0.83 mg/100g) was recorded with M_2 - organic module-2.

The interaction between different levels of FYM and organic modules on chlorophyll content in fresh fruit did not differ significantly, while, significant difference between control and rest of the treatments was registered. Maximum chlorophyll content in fresh fruit *i.e*., 1.19 mg/100g was reported with L_1M_1 (FYM equivalent to 100% RDN + organic module-1) while, control (100 % RDF-100:50:50 kg NPK/ha) recorded 1.98 mg/100g chlorophyll content in fresh fruit. Lowest chlorophyll content (0.61 mg/100g) was reported with L_3M_2 (FYM equivalent to 50% RDN + organic module-2).

L_1M_1 (Farmyard manure equivalent to 100% recommended dose of nitrogen (RDN) + organic module-1) exhibited significantly higher chlorophyll content in the study. The enhanced chlorophyll levels in this treatment can be attributed to the effective supply of essential nutrients to the plants. Chlorophyll synthesis in plants is directly influenced by the availability of physiologically active nutrients such as iron (Fe), nitrogen (N), phosphorus (P), and sulfur (S). The application of farmyard manure equivalent to 100% RDN, along with incorporation of *Trichoderma viride* at 5 kg/ha enriched with neem cake and spraying a 3% panchagavya solution at regular intervals, likely provided optimal levels of macro (N, P, K) and micronutrients (Zn, Cu, Fe, Mn, Mg). This facilitated active mineralization, nutrient mobilization, and increased nutrient uptake, supporting chlorophyll formation. Iron is crucial for chlorophyll synthesis and maintenance of chloroplast structure and function [35] while magnesium plays a role in chlorophyll synthesis and enhances photosynthetic rates [36]. Increase in chlorophyll content can be linked to improved photosynthetic activity in plants, consistent with findings reported by Karanatsidis and Berova [37].

3.7 Percent of Fruit Infestation (%) by Okra Shoot and Fruit Borer

Pooled data with respect to percent of fruit infestation in okra presented in Table 3 revealed that application of different levels of FYM has non-significant effect while, organic modules has found significant on percent of fruit infestation. During the entire okra crop period, minimum mean percent of fruit infestation (6.28%) was recorded in control (100 % RDF-100:50:50 kg NPK/ha + emamectin benzoate 5% SG @ 70 g/200 lit) which is followed by L_1M_1-100% RDF + organic module-1 (10.04% respectively).

There was a significant difference among the organic modules in terms of the percent infestation of okra by shoot and fruit borer, with the lowest infestation recorded in M_1-organic module-1. This module involved spraying 5% neem oil, Beauveria bassiana at 5g/liter, and *Bacillus thuringiensis* at 1kg/ha at 10-day intervals. Nayak et al. [38] demonstrated that applying Biodart (*B. thuringiensis*) and Daman (*B. bassiana*) at 1 kg/ha at specific intervals resulted in less fruit damage, both in terms of infested fruits and weight loss, compared to other compounds. Amin et al. [39] highlighted that *Bacillus thuringiensis* Serovar Kurstaki at 2 ml suspension/liter was the most effective biological control method for sustainable management of okra shoot and fruit borers. The efficacy of entomopathogenic fungi such as *Beauveria bassiana* and *Bacillus thuringiensis* in reducing shoot and fruit borer infestations is supported by the findings of Adsure et al. [40].

There was no significant interaction effect between different levels of farmyard manure (FYM) and organic modules on the percent of fruit infestation. However, a significant difference was observed between the control and the other treatments. The lowest percent of infestation was recorded with the control treatment (100% recommended dose of fertilizers - 100:50:50 kg NPK/ha + emamectin benzoate 5% SG @ 70 g/200 L), which proved highly effective against shoot and fruit borer pests. In studies on brinjal, emamectin benzoate 5% SG applied at 200 g/ha significantly reduced fruit and shoot damage and resulted in higher fruit yields [41,42]. Similarly, emamectin benzoate 5% SG applied at 17.0 g a.i/ha was found highly effective against shoot and fruit borers, achieving an average population reduction of 90.72% after three applications [43]. These results align with findings reported by Shrivastava et al. [44] and Rohith et al. [45].

3.8 Average Number of Jassids Per Leaf

Pooled data recorded on average no. of adults per leaf in okra presented in Table 4 revealed that application of different levels of FYM has non-significant effect on controlling jassids, while, significant difference between organic modules and control was reported. Lowest mean (mean of all sprays) population of jassid per leaf (1.08/leaf), was recorded in control (100 % RDF-100:50:50 kg NPK/ha + imidacloprid 17.8 SL @ 100 ml/acre) which is followed by L_1M_3 (100% RDF + organic module-3) (1.69/leaf).

Organic module-3 (M_3) demonstrated the lowest population of jassids among the organic modules tested. *Lecanicillium lecanii*, a fungal bio-agent known for its efficacy against sucking pests such as jassids, holds significant promise for integrated pest management [46,47]. Combining *L. lecanii* with neemastra proved to be the most effective treatment for reducing jassid

Table 3. Effect of different levels of farmyard manure and organic modules on percent of fruit infestation by okra shoot and fruit borer (Pooled data of 2021-22 and 2022-23)

Percent of fruit infestation (Pooled data of 2021-22 and 2022-23)						
Treatment	**After 6th spray**	**After 7th spray**	**After 8h spray**	**After 9th spray**	**After 10th spray**	**Mean**
FYM levels (L)						
L_1	8.14	13.41	13.58	12.70	10.95	11.76
L_2	8.27	13.94	13.53	13.15	11.05	11.99
L_3	9.23	13.76	13.88	13.82	11.06	12.35
S.Em±	0.030	0.045	0.050	0.039	0.028	
LSD (5%)	NS	NS	NS	NS	NS	
Organic modules (M)						
M_1	6.74	12.66	12.46	10.60	9.39	10.37
M_2	9.32	13.56	14.65	13.50	11.45	12.50
M_3	9.57	14.89	13.89	15.58	12.21	13.23
S.Em±	0.030	0.045	0.050	0.039	0.028	
LSD (5%)	0.089	0.134	0.150	0.115	0.084	
Interaction (L X M)						
L_1M_1	6.28	12.27	12.19	10.15	9.32	10.04
L_1M_2	9.11	13.22	14.27	12.96	11.32	12.18
L_1M_3	9.04	14.75	14.30	15.01	12.19	13.06
L_2M_1	6.40	12.90	12.75	10.36	9.46	10.37
L_2M_2	9.13	13.70	14.82	13.55	11.58	12.56
L_2M_3	9.28	15.22	13.02	15.56	12.11	13.04
L_3M_1	7.55	12.80	12.44	11.30	9.38	10.69
L_3M_2	9.72	13.76	14.86	12.99	11.45	12.56
L_3M_3	10.40	14.70	14.35	16.17	12.32	13.59
S.Em±	0.090	0.135	0.151	0.117	0.084	
LSD (5%)	NS	NS	NS	NS	NS	
Control	3.77	7.06	7.38	6.62	6.55	6.28
S.Em±	0.090	0.135	0.151	0.117	0.084	
LSD (5%)	0.345	0.518	0.580	0.447	0.324	

Factor: 1
L_1: Farmyard manure equivalent to 100% RDN
L_2: Farmyard manure equivalent to 75% RDN
L_3: Farmyard manure equivalent to 50% RDN

Factor: 2
M_1: Organic Module-1
M_2: Organic Module-2
M_3: Organic Module-3

Control: 100% RDF + emamectin benzoate 5% SG @ 70 g/200 lit populations. In okra, application of *L. lecanii* at 7 g/l resulted in higher mortality of jassids (Baladaniya *et al.,* 2010). Spraying *L. lecanii* at 5 g/l three times from 25 days after sowing (DAS), with a 10-day interval between sprays, significantly reduced the incidence of leaf hoppers, thrips, and whiteflies [48]. *Pseudomonas fluorescens*, known for enhancing plant growth through mechanisms like siderophore production, antibiotic synthesis, and promotion of plant growth hormones, is also utilized as a potential bio-protectant [49]. Similar findings were reported by Jaydeep et al. [50].

Interaction effect between different levels of FYM and organic modules has found non-significant effect with respect to jassid population, while, significant difference between control and rest of the treatments was reported. Control (100% RDF-100:50:50kg NPK/ha + imidacloprid 17.8 SL @ 100 ml/acre) has found most effective in controlling jassid population when compared to organic modules. Present findings are in close conformity with the results of Raghuraman and Ajanta [51] who reported that imidacloprid 17.8% SL @ 80 gm a.i./ha significantly suppressed whitefly and jassid populations, and consequently increased the yield in okra. Similar results earlier were reported by Pawar *et al*. [52] Prem Kumar and Ashwin [53] and Jayadeep et al. (2021) [54,55].

Table 4. Effect of different levels of farmyard manure and organic modules on number of jassids per leaf of okra (Pooled data of 2021-22 and 2022-23)

Treatment	After 3rd spray	After 4th spray	After 5th spray	After 6th spray
FYM levels (L)				
L_1	1.99	2.27	2.45	2.14
L_2	2.07	2.25	2.41	2.25
L_3	2.05	2.39	2.55	2.29
S.Em±	0.009	0.013	0.015	0.016
LSD (5%)	NS	NS	NS	NS
Organic modules (M)				
M_1	2.08	2.40	2.58	2.11
M_2	2.85	2.95	3.30	3.19
M_3	1.18	1.57	1.53	1.38
S.Em±	0.009	0.013	0.015	0.016
LSD (5%)	0.026	0.039	0.046	0.048
Interaction (L X M)				
L_1M_1	2.05	2.30	2.53	2.12
L_1M_2	2.78	2.97	3.31	3.03
L_1M_3	1.13	1.55	1.49	1.27
L_2M_1	2.10	2.38	2.51	2.01
L_2M_2	2.89	2.86	3.20	3.28
L_2M_3	1.21	1.53	1.53	1.46
L_3M_1	2.08	2.51	2.68	2.20
L_3M_2	2.89	3.03	3.39	3.25
L_3M_3	1.20	1.64	1.58	1.41
S.Em±	0.026	0.039	0.046	0.049
LSD (5%)	NS	NS	NS	NS
Control	0.72	1.05	0.95	0.75
S.Em±	0.026	0.039	0.046	0.049
LSD (5%)	0.101	0.150	0.178	0.187

Treatment	After 7th spray	After 8th spray	After 9th spray	After 10th spray	Mean
FYM levels (L)					
L_1	2.35	3.22	3.17	2.77	2.55
L_2	2.44	3.13	3.04	2.86	2.56
L_3	2.54	3.26	3.15	2.91	2.64

Treatment	After 7th spray	After 8th spray	After 9th spray	After 10th spray	Mean
S.Em±	0.017	0.015	0.020	0.014	
LSD (5%)	NS	NS	NS	NS	
Organic modules (M)					
M_1	2.35	3.16	3.24	2.75	2.58
M_2	3.39	4.00	3.87	3.79	3.42
M_3	1.60	2.45	2.26	1.99	1.75
S.Em±	0.017	0.015	0.020	0.014	
LSD (5%)	0.050	0.044	0.059	0.041	
Interaction (L X M)					
L_1M_1	2.37	3.17	3.28	2.73	2.57
L_1M_2	3.23	4.04	4.03	3.66	3.38
L_1M_3	1.46	2.45	2.21	1.92	1.69
L_2M_1	2.15	3.19	3.05	2.66	2.51
L_2M_2	3.50	3.82	3.80	3.91	3.41
L_2M_3	1.69	2.38	2.27	2.00	1.76
L_3M_1	2.52	3.12	3.38	2.87	2.67
L_3M_2	3.45	4.15	3.77	3.81	3.47
L_3M_3	1.65	2.52	2.31	2.05	1.80
S.Em±	0.051	0.045	0.060	0.042	
LSD (5%)	NS	NS	NS	NS	
Control	0.94	1.54	1.42	1.29	1.08
S.Em±	0.051	0.045	0.060	0.042	
LSD (5%)	0.195	0.171	0.230	0.159	

Factor: 1

L_1: Farmyard manure equivalent to 100% RDN

L_2: Farmyard manure equivalent to 75% RDN

L_3: Farmyard manure equivalent to 50% RDN

Factor: 2

M_1: Organic Module-1

M_2: Organic Module-2

M_3: Organic Module-3

Control: 100% RDF + imidacloprid 17.8 SL @ 100 ml/acre

4. CONCLUSION

The current study's findings indicated that control treatment (100% RDF-100:50:50 kg NPK/ha) registered highest yield parameters *i.e.,* number of fruits per plant (19.05), highest fruit weight (14.72 g), maximum fruit yield per plant (0.28 kg), maximum fruit yield per hectare (9.52 t/ha) over the other treatments. L_1M_1 (FYM equivalent to 100% RDN + organic module-1) registered higher quality parameters *i.e.,* minimum crude fibre content (7.10%), and maximum chlorophyll content in fresh fruit (1.19 mg/100g). While, minimum mean percent of fruit infestation (6.28%) was recorded in control (100% RDF-100:50:50 kg NPK/ha + emamectin benzoate 5% SG @ 70 g/200 lit) which is followed by L_1M_1 (100% RDF + organic modules-1) (10.09%) and lowest mean population of jassid per leaf (1.08/leaf), was recorded in control (100 % RDF-100:50:50 kg NPK/ha + imidacloprid 17.8 SL @ 100 ml/acre) which is followed by L_1M_3 (100% RDF + organic module-3) (1.69/leaf).

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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