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Impact of Different Crop Production Systems on Insect Pests' Incidence, Soil Microflora and Quality of Spring Tomato under North-Indian Conditions

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ABSTRACT

The impact of different crop production systems was investigated on incidence of insect pests and their natural enemies, soil microflora and enzymatic activity, and quality of fruits produced in spring planted tomato at Ludhiana, Punjab, during 2017 to 2019. Production systems included conventional farming whereby indiscriminate and excessive use of agrochemicals is practiced, organic farming, and farming following Good Agricultural Practice (GAP) with IPM adoption. Higher *Aphis gossypii* and *Helicoverpa armigera* infestation was observed in organic fields followed by IPM and conventional fields. Aphid population showed a negative correlation with maximum and minimum temperature but a positive correlation with relative humidity, while the tomato fruit borer showed a positive correlation with maximum and minimum temperature but negative correlation with relative humidity and rainfall. The mean fruit yield in the farming system following IPM was maximum (50120 Kg ha^{-1}) followed by conventional farmers' fields (408.1 q/ha) and organic fields (403.9 q/ha). The mean spider population under organic conditions (0.39-0.56) was significantly higher than that of IPM (0.26-0.36) and conventional farmers' fields (0.02-0.10). Soil samples from conventional fields revealed the presence of quinalphos and chlorpyriphos, while tomato fruit samples showed the presence of triazophos and mancozeb during 2017 and 2018. In 2017, the flavonoids and percent antioxidant activity in fruits from organic field were higher. The bacterial count in organic and IPM field soil increased from 5.4×10^7 and 4.9×10^7 CFU g^{-1} in 2017 to, respectively, 7.1×10^7 and 6.5×10^7 CFU g^{-1} in 2019. The activity of alkaline phosphatase and urease was highest in organic fields.

Keywords: *Aphis gossipii, Helicoverpa armigera*, Microorganisms, Pesticide residues, Seasonal dynamics, Soil biological properties.

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is one of the world's most popular and commonly farmed vegetables. India is the world's second-largest producer, after China, accounting for about 11 per cent of total global output with annual production of 18.7 MT on 0.88 million hectares (Mondal *et al*., 2019). In Punjab, tomato occupies an area of 10.28 thousand hectares with 266.91 thousand MT production (Anonymous, 2019). Tomato cultivation in India is done under three different production systems, namely, conventional farming, organic farming, and farming following Good Agricultural Practices (GAP) with Integrated Pest Management (IPM) system. Conventional farming is the method that involves frequent use of pesticides and other agrochemicals to get highest possible yield of crop, but this system may compromise on crop quality. Excessive and indiscriminate use of pesticides and agrochemicals often lead to negative impacts like soil and water pollution, toxic residues in the final produce, development of insecticide

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resistance, and induction of resurgence in major insect pests. Organic farming, on the other hand, strives to produce pesticide-residue free food while ensuring healthy soil and water environments. The third system, farming following GAP with IPM removes drawbacks of conventional and organic farming. It employs good agricultural practices recommended by the State Agricultural University for raising a healthy crop while adopting need-based judicious application of agrochemicals.

Tomato productivity is greatly hampered by biotic and abiotic factors (Blay, 2005). In India, about 16 pests feed on tomato, commencing from germination to harvesting stage, which reduces its yield and also degrades its quality. Tomato fruit borer, *Helicoverpa armigera* (Hubner) and aphid, *Aphis gossypii* Glover are amongst the key insect-pests causing yield losses of up to 85-93.7 and 34 per cent, respectively (Islam, 2017). The population fluctuation in insect-pests is largely governed by weather factors like temperature, rainfall, humidity etc., which prevail during the crop growth period and exert a direct influence on insect distribution and development (Mondal *et al.,* 2019; Chavan *et al.,* 2013).

The excessive use of chemical fertilizers and pesticides also deteriorate soil quality, leading to adverse effects on soil productivity. Soil enzymes playing dynamic role in maintenance of soil ecology, fertility, and organic matter decomposition also get affected. Although modern chemical plant protection products are target specific and somewhat environmentally safe, there is always a risk that human exposure to pesticide residues in food products may constitute a potential danger to health (Rembialkowska and Badowski, 2011).

The present investigation was planned to study the impact of indiscriminate and excessive use of agrochemicals in conventional farming system vis-à-vis organic farming and farming following GAP with IPM adoption. The insect-pests diversity under different crop production systems and its relation with various abiotic factors was ascertained. Impact of organic and synthetic agro-inputs on soil properties and quality parameters of tomato fruit was also studied.

MATERIALS AND METHODS

Study area and Data Collection

Studies were conducted on spring-planted tomato crop during three consecutive years, from 2017 to 2019. The experiments in organic farming and farming following GAP with IPM were laid out in field plots of one acre, each. For conventional farming, ten farmers, each with one-acre field, were selected. Tomato cultivars *viz*. Golden 575, Punjab Ratta and Hybrid tomato were cultivated under different farming systems. The details of the inputs added under different farming systems are given in Table 1.

Pest Population Dynamics

The data pertaining to different insect-pests was recorded at weekly intervals in accordance with SMW (Standard Meteorological Week) starting from pest appearance. Correlation and regression equations were calculated to estimate the effects of these abiotic factors on population counts of insect pests. The impact of abiotic factors such as maximum temperature, minimum temperature, relative humidity and rainfall on population dynamics of *H. armigera* and *A. gossypii* was recorded from five plants, selected at random from organic, IPM and conventional farmers' fields, starting from January to June during the period of study. Natural enemies (spiders) population was also recorded.

Analysis of Pesticide Residues

The tomato fruits' and crop soil samples of the three distinct crop production systems were analyzed for presence of pesticides residues using GLC-ECD for

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Table 1. Details of inputs/chemical fertilizers/synthetic pesticides used under different crop production systems.

Organic	• 10 tons of Farm Yard Manure (FYM) of desi cows per acre • Soil treatment for enhancing soil productivity: Organic material for soil treatment was prepared by mixing 10 kg cow dung with 1,500 g jaggery, 1,500 g gram flour in 100 L water, followed by incubation of the mix material for 3 days at 35 °C to allow fermentation. The final product so obtained was added to irrigation water once in a month. • Seed treatment: Organic material for seed treatment was prepared by mixing 5 L cow urine in 5 kg cow dung and 5 g lime soda in 20 L of water, followed by incubation for 30 hours, filtration and final treatment of seed with the filtrate. • Insect pest and disease management: Spray of sour Butter milk (*Khatti lassi)* alone or after mixing turmeric and jaggery for insect pests and viral diseases control; Spray of *Brahma Astra* prepared by mixing 2 kg each of neem (*Azadirachta indica*), Akk (*Calotropis* sp.), Dhatura (*Datura stramonium*) and castor (*Ricinus communis*) leaves in 20 litres of cow urine; and Spray of *Neem Astra* prepared by mixing 2 kg each of neem leaves and cow dung in 200 L of water.
IPM	• 10 tons of Farm Yard Manure (FYM) • 130 kg Urea (55 kg at planting and 75 kg in mid-February); 155 kg SSP (at planting) and 45 kg Murate of Potash (at planting) • Seed treatment with Captan @ 3g per kg of seed • Need based spray of Malathion @ 400 mL acre^{-1} for aphids, and Flubendiamide 39.35 SL @ 30 mL acre^{-1} for tomato fruit borer, and Mancozeb 75% WP @ 600 mL acre^{-1} for early blight of tomato.
Conventional farming	• Synthetic fertilizers: 50-200 kg Urea (split in 2-3 doses) along with 50-100 kg DAP and 50 kg Murate of Potash • Insect pest and disease management: Insecticides in varying dosages used indiscriminately by conventional farmers included Malathion 50 EC, Emamectin benzoate 5% SG, Chlorantraniliprole 18.5 SC, Flubendiamide 39.35 SL, Chlorpyriphos 20 EC, Profenophos 50EC, Imidacloprid 17.8 SL, Regent 5 SC, Prefenofos 40% + cypermethrin 4% EC, β-cyfluthrin+imidacloprid while fungicides used were Ridomil MZ, Sectin 60 WG, Mancozeb 75% WP, Mancozeb (64% w/w)+Metalaxyl-M (4% w/w), and mixture of Fenamidone 10%+Mancozeb 50%

organochlorines and synthetic pyrethroids, and GLC-FPD for analysis of organophosphates (Anastassiades and Lehotay, 2003). Confirmation of pesticides detected was done on GC-MS. For tomato fruits, 500 g representative sample from each crop production system was crushed using high volume homogenizer. A sub-sample of 15 g crushed fruits, obtained from above, was put into a 50 mL centrifuge tube and further homogenized using high speed homogenizer (Heidolph Silent Crusher-M®) for 3 minutes at 15,000 rpm while adding 30 mL acetonitrile and 7 mL of distilled water to it. For phase separation, 10 g sodium chloride was added. An aliquot of 10 mL acetonitrile layer transferred over 10±0.1 g anhydrous sodium sulfate was subjected to cleanup by Dispersive Solid Phase Extraction (DSPE). An aliquot of 6 mL acetonitrile was taken in a test tube containing 0.15±0.01 g PSA sorbent and 0.90±0.01 g anhydrous $MgSO_4$ and the contents were thoroughly vortex on vortex shaker, followed by centrifugation at 2,500 rpm for 1 min. Finally, a 4 mL aliquot was concentrated at Turbo vap till dryness, and final volume was made up to 2 mL with acetone for the estimation of pesticide residues. For soil samples analysis, the same methodology was followed, except a sub-sample of 10 g and addition of 20 mL of acetonitrile to the 50 mL centrifuge tube.

Analysis of Soil Biological Parameters

The surface soil samples (0-15 cm) from all the selected fields were collected before harvesting the crop. The samples were air-

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dried, processed, and analyzed for various biological properties. The data on soil parameters were interpreted by categorizing the farmers based on the recommended dose of N fertilizer: F(N)= Farmers using the recommended dose of N fertilizer; F(MH)= Farmers using 25% more N than the recommended dose of N fertilizer; F(H)= Farmers using of the recommended dose of N fertilizer; F(VH)= Farmers using of the recommended dose of N fertilizer. The activity of soil enzymes *viz*. dehydrogenases was determined by method described by Ohlinger (1996), urease as per Alef and Nannipieri (1998), and Alkaline Phosphatase (AKP) as described by Alef *et al* (1998).

Analysis for Quality Parameters in Tomato Fruits

The tomato fruits harvested from the selected organic, IPM and conventional farmers' fields were analyzed for flavonoids (Woisky and Salatino, 1998) and anti-oxidants (Kaur and Kapoor, 2002).

RESULTS

Population Dynamics of Insect Pests

***Aphis gossypii*:** During 2017, the aphids first appeared in the 8th SMW, while in 2018 and 2019, the aphids appeared in the 10th SMW. The population of aphids reached its peak of 10.23/3 leaves in 9th SMW during 2017, 5.07 in 11th SMW during 2018, and 4.97 in 11th SMW during 2019 in the respective organic fields. Organic fields showed higher aphid infestation in all the years of study followed by IPM and conventional fields (Figure 1). The aphid population was higher in the first year (4.20/3 leaves in organic, 2.78/3 leaves in IPM, and 2.15/3 leaves in conventional fields) as compared to 2nd (3.41/3 leaves in organic, 2.10/3 leaves in IPM, and 1.06/3 leaves in conventional fields), and 3rd year (3.37/3 leaves, 2.08/3 leaves and 1.07/3 leaves in organic, IPM and conventional fields, respectively) (Table 2). Correlation analysis done between the pooled population and meteorological parameters for three years (2017-19) revealed a negative correlation between aphids' population and maximum and minimum temperature, but a positive correlation with relative humidity in organic, IPM, and conventional fields (Table 3). The maximum value of regression coefficient (R^2) of aphid population was 0.3735, 0.4561 and 0.3638 with relative

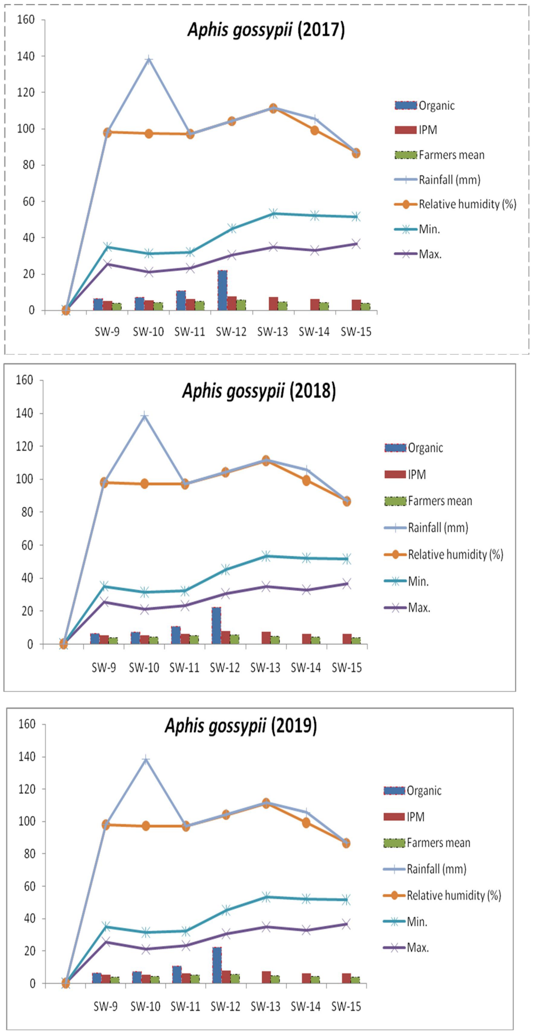

Figure 1. Seasonal incidence of *Aphis gossypii* under different crop production systems.

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Table 2. Seasonal incidence of tomato aphid and tomato fruit borer and abundance of natural enemies (spiders) under different crop production systems.

Season >	2017			2018			2019		
Field >	Org	IPM	F Mean	Org	IPM	F Mean	Org	IPM	F Mean
Aphis gossypii (No./3 leaves)	4.20	2.78	2.15	3.41	2.10	1.06	3.37	2.08	1.07
Helicoverpa armigera (%)	9.69	5.79	4.28	8.57	2.75	3.19	8.29	2.69	2.96
Spiders (Number)	0.39	0.26	0.02	0.51	0.27	0.07	0.56	0.36	0.10

Table 3. Correlation coefficient between insect pests and weather parameters.

	Correlation coefficient (r)					
Weather parameters	Max temp (℃)	Min temp (℃)	RH (%)	Rainfall (mm)	Aphid	Fruit borer
			Organic field			
Max temp (℃)	1					
Min temp (℃)	0.979523	1				
RH (%)	-0.9519	-0.96451	1			
Rainfall (mm)	-0.08702	-0.00732	-0.06564	1		
Aphid	-0.50337	-0.61109	0.611146	-0.34993	1	
Fruit borer	0.660388	0.718653	-0.63685	-0.30775	-0.46681	1
			IPM adopted field			
Max temp (℃)	1					
Min temp (℃)	0.979523	1				
RH (%)	-0.9519	-0.96451	1			
Rainfall (mm)	-0.08702	-0.00732	-0.06564	1		
Aphid	-0.54888	-0.63636	0.675326	-0.15695	1	
Fruit borer	0.54691	0.65775	-0.73976	-0.34787	0.824011	1
			Conventional field			
Max temp (℃)	1					
Min temp (℃)	0.979523	1				
RH (%)	-0.9519	-0.96451	1			
Rainfall (mm)	-0.08702	-0.00732	-0.06564	1		
Aphid	-0.47514	-0.55933	0.603149	0.13377	1	
Fruit borer	0.20555	0.31222	-0.429368	-0.42752	0.688984	1

Significant at 5% level; Significant at 5% level.

humidity in organic, IPM, and conventional fields, respectively. Lowest R^2 value was observed with rainfall (0.1224, 0.0246, and 0.0179, respectively, in the three test fields).

***Helicoverpa armigera*:** *H. armigera* incidence was observed during 9th SMW in 2017 and 14th SMW during 2018 and 2019. A low level of *H armigera* population was recorded in the 9th SMW in three test modules when the average temperature was 17.5 ˚C during 2017 crop season. A persistently high population of *H. armigera* occurred in 10th, 11th, and 12th SMW in the organic and IPM fields, while in the conventional farmers' fields, the population increased from 9th to 12th SMW while it declined afterwards (Figure 2). In 2018, the fruit borer population increased from 14th to 19th SMW in the organic field (3.76-15.26), while the IPM and conventional farmers' fields witnessed maximum *H. armigera* population in 15th SMW, which decreased during the 16th and 17th SMW. Likewise, an increase in fruit borer population was observed from 14th-19th SMW (3.33-13.77) in the organic field during 2019. The fruit borer population was higher in the first year (9.69% of the total fruits content in organic, 5.79% in IPM, and 4.28% in conventional fields) as compared to 2nd (8.57% in organic, 2.75% in IPM, and 3.19% in

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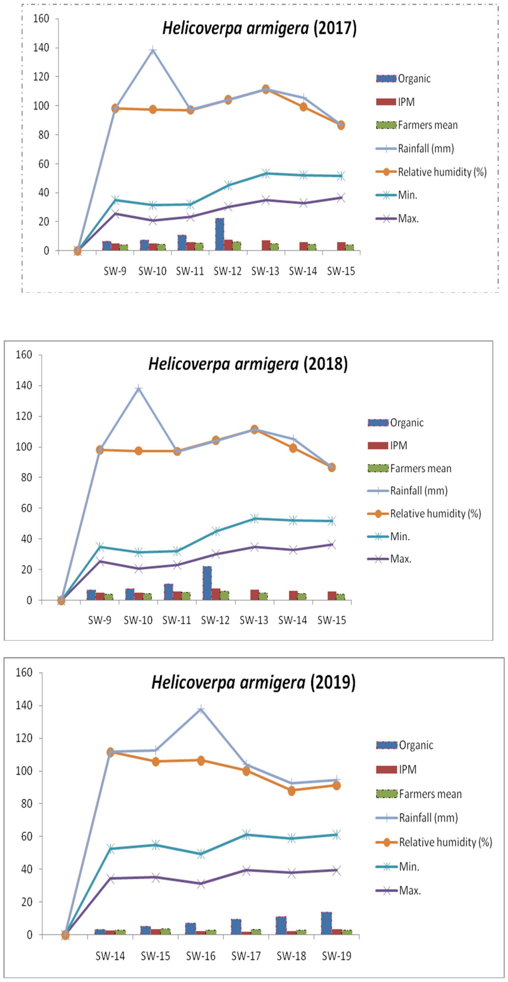

Figure 2. Seasonal incidence of tomato fruit borer, *Helicoverpa armigera* under different crop production systems.

conventional fields) and 3rd year (8.29, 2.69 and 2.96% in organic, IPM and conventional fields, respectively) (Table 2). The analysis of pooled data also shows maximum *H. armigera* population in the organic fields as compared to IPM and conventional fields during all the years. Furthermore, the fruit borer population in the organic, IPM, and conventional fields showed a positive correlation with maximum and minimum temperature and a negative correlation with relative humidity and rainfall (Table 3). The highest R^2 value for *H. armigera* population was 0.5165 with minimum temperature in the organic field, while it was 0.5472 and 0.1844 with relative humidity in IPM and conventional field, respectively.

Tomato Yield

The mean tomato fruit yield in the farming following GAP with IPM adoption, was maximum (50122 Kg ha^{-1}) followed by conventional farmers' field (40800 Kg ha^{-1}) and organic field (40390 Kg ha^{-1}). The conventional tomato growers obtained the mean tomato fruit yield in the range of 369.2 to 42650 Kg ha^{-1}. The yield trends observed in the study showed that lower rates of application of pesticides in IPM might be more desirable for environment safety and to reduce the cost of cultivation.

Natural Enemies

The mean spider population was found to be substantially higher under organic field conditions (0.39, 0.51, and 0.56 spiders/plant, respectively, during 2017, 2018, and 2019). This was followed by farming GAP with IPM adoption (0.26, 0.27 and 0.36 spider/plant, respectively during 2017, 2018, and 2019), while leas in conventional farmers' fields (0.02, 0.07 and 0.10 spiders/plant, respectively, during 2017, 2018 and 2019 (Table 3).

Pesticide Residues in Soil and Tomato Fruits

Analysis of crop soil and tomato fruits for pesticide residues from organic and IPM fields showed that all tested samples were free of pesticides residue. However, the soil samples collected from conventional farmers' fields revealed presence of quinalphos and chlorpyriphos, while the tomato fruit samples of conventional farmers' fields showed the presence of triazophos and mancozeb during 2017 and 2018, respectively (Table 4). During 2019 crop season, all samples of soil and tomato fruits were free from any pesticides

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Table 4. Soil biological properties under different crop production systems.

Crop season >	2017			2018				2019				
Field >	*Organic	*IPM	*$F_{(VH)}$	*Organic	*IPM	*$F_{(MH)}$	*$F_{(VH)}$	*Organic	*IPM	*$F_{(N)}$	*$F_{(MH)}$	*$F_{(H)}$
Bacteria (CFU g^{-1} soil)	$5.4×10^7$	$4.9×10^7$	$3.7×10^7$	$7.9×10^7$	$7.2×10^7$	$5.0×10^7$	$5.9×10^7$	$7.1×10^7$	$6.5×10^7$	$4.2×10^7$	$3.3×10^7$	$4.1×10^7$
Actinomycetes (CFU g^{-1} soil)	$4.5×10^7$	$3.9×10^7$	$3.1×10^6$	$6×10^6$	$5.8×10^6$	$2.2×10^6$	$2.3×10^6$	$7.7×10^6$	$6.5×10^6$	$4.9×10^6$	$4.7×10^6$	$4.0×10^6$
Fungi (CFU g^{-1} soil)	$6.5×10^4$	$4.6×10^4$	$3.9×10^3$	$6.2×10^4$	$3.5×10^4$	$4.5×10^3$	$5.1×10^3$	$8.9×10^3$	$8.1×10^3$	$5.4×10^3$	$6.2×10^3$	$4.5×10^3$
Earthworms (Numbers)	2-4	0-1	Nil	2-3	1-3	1-2	Nil	2-3	1-2	Nil	Nil	Nil
Alkaline phosphatase (µg PNP g^{-1} h^{-1})	72	56	41.1	76	69	48.6	45.2	82	77	48.5	69	65.5
Dehydrogenase (µg TPF g^{-1} h^{-1})	10.2	8.61	7.99	12.06	9.84	10.21	9.91	13.69	11.21	7.88	10.50	6.63
Urease (µg g^{-1} h^{-1})	553	495	423	490	456	402	420	503	436	343.7	358	387.5

F(N)= Farmers using recommended dose of N fertilizer; F(MH) = Farmers using 25% more N than the recommended N fertilizer.
F(H)= Farmers using >50% of the recommended N fertilizer; F(VH)= Farmers using >75% of the recommended N fertilizer.
* Mean value of 3 replications for each treatment.

residues. This may be the result of consistent efforts made to educate conventional farmers regarding ill effects of indiscriminate use of pesticides on fruit quality, natural enemies' abundance, and human health.

Biological Properties

The soil samples from organic fields showed relatively higher number of earthworms, higher population of fungi, bacteria and actinomycetes, and enhanced activity of enzymes, dehydrogenase, alkaline phosphatase and urease as compared to soil samples from IPM and conventional fields (Table 5). Mean earthworm count was higher in organic field in contrast to IPM and conventional fields during the three seasons. The bacterial count in soil of organic and IPM field increased from 5.4×10^7 and 4.9×10^7 CFU g^{-1} in 2017 to 7.1×10^7 and 6.5×10^7 CFU g^{-1} in 2019. Actinomycetes count in soil of organic and IPM field was 4.5×10^7 and 3.9×10^7 CFU g^{-1} soil during 2017, 6×10^6 and 5.8×10^6 CFU g^{-1} soil during 2018, and 7.7×10^6 and 6.5×10^6 CFU g^{-1} soil during 2019. The count for fungal colonies recorded using 10^{-3} and 10^{-4} dilutions was observed to be 6.5×10^4 CFU g^{-1} soil in organic field and 4.6×10^4 CFU g^{-1} soil in IPM field in 2017, which decreased to 6.2×10^4 CFU g^{-1} in organic field and 3.5×10^4 CFU g^{-1} in IPM field in 2018. This again increased to 8.9×10^3 CFU g^{-1} in organic field and 8.1×10^3 CFU g^{-1} in IPM field in 2019 season, respectively. The bacterial, actinomycetes and fungal count in conventional field was lower than both organic and IPM fields in the final season. The soil samples from organic fields showed relatively higher population of fungi, bacteria and actinomycetes as compared to soil samples from IPM and conventional fields in all the three growing seasons (Table 5). Activity of dehydrogenase enzyme was highest in organic field followed by IPM and conventional fields in 2017, 2018, and 2019, respectively. The activity of alkaline phosphatase was highest in organic fields (72, 76 and 82 µg PNP g^{-1} h^{-1} in 2017, 2018, and 2019, respectively) followed by IPM field (56, 69 and 77 µg PNP g^{-1} h^{-1} in 2017, 2018, and 2019, respectively). The activity was lower in all the fields following conventional practices throughout the study period. Similarly, urease enzyme activity was higher in soil under organic practices (553, 490 and 503 µg g^{-1} h^{-1} in 2017, 2018, and 2019, respectively) than those under IPM and conventional practices.

Quality of Tomato Fruits

Total flavonoids and antioxidants content in tomato fruits were measured at maturity. A significantly higher amount of flavonoids (1.65, 1.66, and 2.11 mg Rutin Equivalent (RE) g^{-1} during, respectively, 2017, 2018, and 2019 crop seasons) and antioxidants activity (98.7%, 97.0%, and 93.6 % during, respectively, 2017, 2018 and 2019 crop seasons) was recorded in the fruits harvested from organic fields in contrast to fruits harvested from conventional farmers' fields (Table 6). Tomato fruits harvested from fields with 'farming following GAP with IPM adoption' recorded 1.34, 1.36 and 1.75 mg RE g^{-1} flavonoids, and 93.2, 94.0, and 93.2% antioxidant activity during, respectively, 2017, 2018, and 2019 crop seasons in contrast to 1.10, 1.02-1.32 and 1.13-1.36 mg RE g^{-1} flavonoids, and 87.5, 87-91, and 89.1-91.15% antioxidant activity during the respective years in tomato fruits harvested from conventional farmers' fields.

DISCUSSION

In the present study, population of the aphid *A. gossypii* reached its peak in 9th–11th SMW during the three years, in line with the findings of Kaushik (2011) who reported *A. gossypii* population gradually increased and attained the maximum at about 8th SMW. Similarly, the negative correlation between the aphid population and mean maximum and minimum temperature, in our study was

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Table 5. Pesticide residue analysis in tomato fruits samples and soil.

Crop production system	Substrate	2017	2018	2019
Organic	Soil	BDL	BDL	BDL
	Fruits	BDL	BDL	BDL
IPM	Soil	BDL	BDL	BDL
	Fruits	BDL	BDL	BDL
Farmer's practice	Soil	Quinalphos (0.18)	Chlorpyriphos (0.03)	BDL
	Fruits	Triazophos (0.06)	Mancozeb (1.34)	BDL

Limit of quantification: Organochlorines= 0.01 mg kg^{-1}; Organophosphates= 0.05 mg kg^{-}1, Synthetic pyrethroids = 0.1 mg kg^{-1} and, Mancozeb= 0.05 mg kg^{-1}

Table 6. Quality parameters of tomato fruits produced following organic, IPM and conventional practices**.**

Crop season >	2017			2018				2019				
Field >	Organic	IPM	$F_{(VH)}$	Organic	IPM	$F_{(MH)}$	$F_{(VH)}$	Organic	IPM	$F_{(N)}$	$F_{(MH)}$	$F_{(H)}$
Flavonoids (mg RE/g)	1.65	1.34	1.10	1.66	1.36	1.02	1.32	2.11	1.75	1.13	1.32	1.36
Antioxidants (% antioxidant activity)	98.7	93.2	87.5	97	94	87	91	93.6	93.2	89.1	90.1	91.15

F(N)= Farmers using recommended dose of N fertilizer; F(MH) = Farmers using> 25% of the recommended N fertilizer; F(H)= Farmers using > 50% of the recommended N fertilizer; F(VH)= Farmers using > 75% of the recommended N fertilizer.

in coherence with Das *et al*. (2019), who reported a significant negative correlation between aphid population and maximum temperature, minimum temperature, and Growing Degree Days (GDD). Furthermore, our studies are in full agreement with the findings of Kataria and Kumar (2015) that showed a negative correlation between aphids and lower temperature. Yaqoob *et al.* (2019) also supported the present findings where aphid count had significant and positive correlation with relative humidity (r= 0.266). On the contrary, Mahmood *et al.* (1990) reported a positive but non-significant correlation between aphid, *Lipaphis erysimi* population in tomato and mean temperature. Kachave *et al.* (2020) also observed a positive correlation between tomato fruit borer population and maximum temperature, while they reported a negative correlation with minimum temperature, morning relative humidity, and rainfall. A persistently high population of *H. armigera* in 10-19 SMW and a positive correlation between fruit borer population and mean maximum and minimum temperature in our study are in line with Kharpuse (2005) and Harshita *et al.* (2018), who observed peak fruit borer population in 12 SMW and a positive correlation between *H. armigera* population and maximum and minimum temperature, but a negative association with average relative humidity. Sharma *et al.* (2010) also reported *H. armigera* population to be negatively correlated with mean relative humidity and rainfall. Wakil *et al.* (2010) and Zafar *et al.* (2013) also reported a positive correlation between larval population and fruit borer infestation in tomato and temperature, but a negative

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interaction with relative humidity. During our three years of experimentation, higher mean spider population under organic and farming following GAP with IPM adoption are in agreement with Miranda *et al.* (2005), who observed that overuse of insecticides reduced natural enemy populations and affected the human health, either by contaminated fruits, or by contaminating soil. Drinkwater *et al.* (1995) observed higher population of natural enemies and predators in the organic tomato production system in California (USA).

The maximum mean tomato fruit yield of 501.2 q/ha in the crop production system following GAP with IPM adoption, followed by conventional farmers' field (408.1 q/ha) and organic field (403.9 q/ha) is supported by Gajanana *et al.* (2006) who reported the adoption of IPM technology to increase tomato yields of IPM farms by 46%. Contamination of tomato fruits and soil samples of conventional farmers' fields with pesticides residues during the first two years in our study are in agreement with Zawiyah *et al.* (2007) who reported pesticide residues in 30% of tomato fruits and 23.3% in chili in farmers' fields where overuse of pesticides was practiced.

An analysis of soil enzymatic activity is an indicator of microbial biomass, soil quality, fertility, and productivity (Winding *et al.,* 2005). Our findings of higher activity of dehydrogenase, alkaline phosphatase and urease enzymes in organic field followed by IPM and conventional fields are supported by Kumari and Charya (2004) and Tiwari *et al.* (2019), who reported significant positive correlation between soil enzymatic activities and microbial population in organic fields. Lower activity of dehydrogenase, alkaline phosphatase, and urease enzymes in conventional farmers' fields are supported by Jastrzebska and Kucharski (2007), who observed fungicide contamination of the soil to significantly inhibit the enzymatic activity of dehydrogenases and urease.

Tomatoes are a good source of antioxidants, vitamin C carotenoids, phenolic compounds and phytochemicals (Ilahy *et al.*, 2011; Uthairatanakij *et al.*, 2017). Organically grown fruits and vegetables have higher levels of vitamin C and antioxidant activity than conventionally grown products (Barron, 2010). The present study also validates positive influence of organic supplements added to organic field, in terms of significantly higher amount of flavonoids and antioxidants activity in the fruits harvested from organic fields, in contrast to fruits harvested from conventional farmers' fields. Rocchetti *et al.* (2022) reported significantly higher total flavonoid content (0.95 mg g^{-1} of dry weight) in tomato fruits from organic farming system than conventionally grown tomatoes (0.74 mg g^{-1} of dry weight). Earlier, Verma *et al*. (2015) observed higher antioxidant activity in organically grown tomatoes in contrast to conventionally grown tomatoes.

This study concluded that different crop production systems do influence the population of different insect-pests and their natural enemies. Among abiotic factors, maximum and minimum temperatures have much greater impact on the population dynamics of insect pests. The soil of organic fields harbours higher microbial load and high enzymatic activity that lead to production of better quality tomato fruits in terms of flavonoids and antioxidants. Indiscriminate use of fertilizers and pesticides pose deleterious effect on soil microbes and enzyme activity, in addition to leaving toxic pesticide residues in soil and fruits. Farming following GAP with IPM adoption is the most promising and viable system of crop production that ensures effective insect pests management along with pesticide residues free produce of better quality. The organic and IPM approaches can work together to address the challenge of food and soil contamination with pesticide residues along with production of quality produce to safeguard human health.

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REFERENCES

1. Alef, K. and Nannipieri, P. 1998. Urease Activity. In: "*Methods in Applied Soil Microbiology and Biochemistry*". Academic Press, Harcourt Brace & Company, Publ., London, PP. 316–320.
2. Alef, K., Nannipieri, P. and Trasar, C. 1998. Phosphatase Activity. In: "*Methods in Applied Soil Microbiology and Biochemistry*", (Eds.): Alef K. and Nannipieri P. Academic Press, Harcourt Brace & Company, Publ., London, PP. 335–344.
3. Anastassiades, M. and Lehotay, S. J. 2003. Fast and Easy Multiresidue Method Employing Acetonitrile Extraction/Partitioning and "Dispersive Solid-Phase Extraction" for the Determination of Pesticide Residues in Produce. *J. AOAC Int.,* **86(2):** 412-431.
4. Anonymous, 2021. Package of Practices for Cultivation of Vegetables. Punjab Agricultural University, Ludhiana, Punjab, India. PP. 200.
5. Barron, J. 2010. Organic vs Conventional. *Nat. Health Newslett.,* **9(1):**11.
6. Blay, E. 2005. Commercial Tomato Production in Ghana. In: "Handbook of Crop Protection in Ghana: An IPM Approach", (Eds.): Kyofa-Boamah, M., Blay, E., Braun, M. and Kuehn, A. **5**: 139-156
7. Chavan, S. M., Kumar, S. and Arve, S. S. 2013. Population Dynamics and Development of Suitable Pest Management Module against Major Insect Pests of Tomato (*Solanum lycopersicum*), *J. Appl. Hortic.,* **15:** 150-155.
8. Das, S., Tejani, D. N., Patel, J. C., Desai, A. G., Desai, A. I. and Gangwar, G. P. 2019. Effect of Weather Parameters on Population Dynamics of Mustard Aphid. *Int. J. Curr. Microbiol. App. Sci.*, **8(4):** 1648-1653.
9. Drinkwater, L. E., Letourneau, D. K., Workneh, F., Van Bruggen, A. H. C. and Shennan, C. 1995. Fundamental Differences between Conventional ad Organic Tomato Agroecosystems in California. *Ecol. Appl.,* **5:** 1098-1112.
10. Gajanana, T. M., Krishna Moorthy, P., Anupama, H. L., Raghunatha, R. and Kumar, G. 2006. Integrated Pest and Disease Management in Tomato: An Economic Analysis. *Agric. Econ. Res. Rev.,* **19:** 269-280.
11. Harshita, A. P., Saikia, D. K., Anjumoni Deeve, B. L. and Phukan, S. N. 2018. Seasonal Incidence of Fruit Borer, *Helicoverpa armigera* and Its Eco-Friendly Management in Tomato, *Solanum lycopersicum. Int. J. Chem. Stud.,* **6:** 1482-1485.
12. Ilahy, R., Hdider, C., Lenucci, M. S., Tlili, I. and Dalessandr, G. 2011. Phytochemical Composition and Antioxidant Activity of High-Lycopene Tomato (*Solanum lycopersicum* L.) Cultivars grown in Southern Italy. *Sci. Hort.,* **127:**255-261.
13. Islam, M. A., Islam, S., Akter, A., Rahman, M. H. and Nandwani, D. 2017. Effect of Organic and Inorganic Fertilizers on Soil Properties and the Growth, Yield and Quality of Tomato in Mymensingh, Bangladesh. *Agriculture.,* **7(3):** 1-7.
14. Jastrzebska, E. and Kucharski, J. 2007. Dehydrogenases, Urease and Phosphatases Activities of Soil Contaminated with Fungicides. *Pl Soil Environ.,* **53:**51–57.
15. Kachave, D. R., Sonkamble, M. M. and Patil,S. K. 2020. Population Dynamics of Major Insect Pests Infesting to Tomato, *Lycopersicon esculentum* (Miller). *J. Pharmacogn. Phytochem.,* **9**: 344-348.
16. Kataria, R. and Kumar, D. 2015. Population Dynamics, Biology of Cotton Aphid, *Aphis gossypii* (Glover) and Its Associated Natural Enemies in Vadodara, Gujarat. *Int. J. Sci. Nat.,* **6(3):**411-420.
17. Kaur, C. and Kapoor, H. C. 2002. Antioxidant Activity and Total Phenolic Content of Some Asian Vegetables. *Int. J. Food Sci. Technol.,* **37:**153-161.7
18. Kaushik, C. 2011. Incidence of Aphid, *Aphis gossypii* Glover (Hemiptrea: aphidae) on Tomato Crop on Agro Climatic Condition of North part of West Bengal, India, *World J. Zool.,* **6**: 187-191.

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19. Kharpuse, Y. K. 2005. Studies on Seasonal Incidence and Role of Botanical against Major Insect Pests of Tomato (*Lycopersicon esculentum* M.). M.Sc. (Ag.) (Ent.), Thesis Submitted to JNKVV, Jabalpur (MP), PP.1-53.
20. Kumar, A. 2004. Industrial pollution and management. In: "*Study of Correlation of Physical, Chemical and Biological Characteristics with Catalase Activity in Industrially Polluted and Unpolluted Soils of Warangal (D.T.)*", (Eds.): Kumari, B. L. and Charya, M. A. APH Publishing, New Delhi, PP. 134-138.
21. Mahmood, T., Khokhar, K. M., Banaras, M. and Ashraf, M. 1990. Effect of Abiotic Factors on Population of Okra. *Pak. J. Agric. Res.,* **11:** 284-286.
22. Miranda, M., Picanço, M. C., Zanuncio, J. C., Bacci, L. and Silva, E. M. D. 2005. Impact of Integrated Pest Management on the Population of Leafminers, Fruit Borers, and Natural Enemies in Tomato. *Ciencia Rural.,* **35(1):** 204-208.
23. Mondal, B., Mondal, P., Das, A. and Bhattyacharyya, K. 2019. Seasonal Incidence of Different Insect Pests of Tomato (*Lycopersicon esculentum* Mill.) and Their Correlation with Abiotic Factor in Lateritic zone of West Bengal. *J. Entomol. Zool. Studies.,* **7(1):** 1426-1430.
24. Ohlinger, R. 1996. Dehydrogenase Activity with the Substrate TTC. In: "*Methods in Soil Biology*", (Eds.): Schinner, F., Ohlinger, R. and Kandeler, E. Springer, Berlin, PP. 241–243.
25. Rembialkowska, E. and Badowski, M. 2011. Pesticides Residues in the Organically Produced Food. In: "*Pesticides in the Modern World - Effects of Pesticides Exposure*". InTech; 2011. Available from: http://dx.doi.org/10.5772/18266
26. Rocchetti, G., Senizza, B., Zengin, G., Bonini, P., Bontempo, L., Camin, F., Trevisan, M. and Lucini, L. 2022. The Hierarchical Contribution of Organic vs. Conventional Farming, Cultivar, and Terroir on Untargeted Metabolomics Phytochemical Profile and Functional Traits of Tomato Fruits. *Front. Plant Sci.,* **13:** 1-11.
27. Sharma R. P., Swaminathan, R. and Bhati, K. K. 2010. Seasonal Incidence of Shoot and Fruit Borer of Okra with Climatic Factors in Udaipur Region of India. *Asian J. Agric. Res.,* **4:** 232-236.
28. Tiwari, R., Dwivedi, B. S., Sharma, Y. M., Sharma, A. and Dwivedi, A. K. 2019. Activities of β-glucosidase, Phosphatase and Dehydrogenase as Soil Quality Indicators: A Review. *Int. J. Curr. Microbiol. App. Sci.,* **8(6):** 834-846.
29. Uthairatanakij, A., Sukanya, Aiamla-Or, Jitareerat, P. and Maneenoi, A. 2017. A Preliminary Comparison of Antioxidants of Tomato Fruit Grown under Organic and Conventional Systems. *Horticulturae.,* **3:** 21.
30. Verma, S., Sharma A., Kumar R., Kaur, C., Arora, A., Shah, R. and Nain, L. 2015. Improvement of Anti-Oxidant and Defense Properties of Tomato (var. Pusa Rohini) by Application of Bioaugmented Compost. *Saudi J. Biol. Sci.,* **22:** 256-264.
31. Wakil W., Ghazanfar, M. U., Kwon, Y. J., Qayyum, M. A. and Nasir F. 2010. Distribution of *Helicoverpa armigera* Hübner (Lepidoptera:Noctuidae) in Tomato Fields and Its Relationship to Weather Factors. *Entomol Res.,* **40:** 290–297.
32. Winding A., Hund-Rinke, K. and Rutgers, M. 2005. The Use of Microorganisms in Ecological Soil Classification and Assessment Concept. *Ecotoxicol. Environ. Saf.,* **62:** 230–248.
33. Woisky, R. G. and Salatino, A. 1998. Analysis of Propolis: Some Parameters and Procedures for Chemical Quality Control. *J. Apicultural Res.,* **37(2):** 95-105.
34. Yaqoob, M., ul Ain, Q. And Ayoub, L. 2019. Seasonal Incidence of Aphid, *Aphis gossypii* Infesting Okra and Its Relation with Weather Parameters. *J. Ent. Zool. Stud.,* **7(4):**672-674.
35. Zafar, K., Suhail, A., Arshad, M. and Arif, J. M. 2013. Impact of Weather Factors on Population Fluctuation of *H. armigera* on Sunflower. *Pak. J. Nutr.,* **12:** 50-54.
36. Zawiyah, S. Y., Man, Y. C., Nazimah, S. A., Chin, C. K., Tsukamoto, I., Hamanyza, A. H. and Norhaizan, I. 2007. Determination of Organochlorine and Pyrethroid Pesticides in Fruit and Vegetables Using SAX/PSA Clean-up Column. *Food Chem.,* **102(1):** 98-103.

اثر سامانه‌های مختلف تولید زراعی بر بروز آفات حشرات، میکرو فلور خاک و کیفیت گوجه فرنگی بهاره در شرایط شمال هند

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چکیده

اثر سامانه‌های مختلف تولید محصول بر بروز آفات حشرات و دشمنان طبیعی آنها، میکرو فلور خاک و فعالیت آنزیمی و کیفیت میوه‌های تولید شده در گوجه‌فرنگی بهاره در لودیانا (Ludhiana)، پنجاب، طی سال‌های ۲۰۱۷ تا ۲۰۱۹ بررسی شد. سامانه های تولید شامل کشاورزی رایج که در آن استفاده بی رویه و بیش از حد از مواد شیمیایی کشاورزی انجام می شود، کشاورزی آلی (ارگانیک)، و کشاورزی با روش های خوب کشاورزی (GAP) با پذیرش IPMبود. آلودگی بیشتر با*Aphis gossypii* و *Helicoverpa armigera* در مزارع آلی و به دنبال آن IPM و مزارع معمولی مشاهده شد.نیز، جمعیت شته با حداکثر و حداقل دما همبستگی منفی ولی با رطوبت نسبی همبستگی مثبت نشان داد، در حالی که حشره خوار گوجه فرنگی با حداکثر و حداقل دما همبستگی مثبت و با رطوبت نسبی و بارندگی همبستگی منفی نشان داد. میانگین عملکرد میوه در سامانه کشاورزی با IPM حداکثر (۵۰۱.۲q/ha) و سپس مزارع کشاورزان معمولی(q/ha ۴۰۸.۱) و مزارع ارگانیک(q/ha ۴۰۳.۹) بود. میانگین جمعیت کنه (spider) در شرایط آلی (۰/۵۶-۰/۳۹) به‌طور معنی‌داری بیشتر از مزارع IPM (۰/۳۶-۰/۲۶) و مزارع کشاورزان معمولی (۰/۱۰-۰/۰۲) بود. نمونه‌های خاک از مزارع معمولی وجود کوینالفوس (chlorpyriphos) و کلرپیریفوس(chlorpyriphos) را نشان داد، در حالی که نمونه‌های میوه گوجه‌فرنگی وجود تریازوفوس(triazophos) و مانکوزب (mancozeb) را طی سال‌های ۲۰۱۷ و ۲۰۱۸ نشان داد. در سال ۲۰۱۷، فلاونوئیدها و درصد فعالیت آنتی‌اکسیدانی در میوه‌های مزرعه آلی بیشتر بود. تعداد باکتری ها در خاک مزرعه آلی و IPM از ۵.۴ x۱۰^{۷} و ۴.۹ x۱۰^{۷} برحسب CFU g^{-1} در سال ۲۰۱۷ به ترتیب در سال ۲۰۱۹ به ۷.۱ x۱۰^{۷} و ۶.۵ x ۱۰^{۷} CFU g^{-1} افزایش یافت. فعالیت آلکالن فسفاتاز و اوره آز در مزرعه های آلی بالاترین میزان بود.

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