Towards Sustainable Onion Seed Production: An In-depth Analysis of Pest Control Practices, Knowledge Gaps, and Pollinator's Awareness among Onion Seed Farmers in Maharashtra, India

Abstract:

A roving survey was conducted to study the pesticide use pattern by interviewing the farmers growing onion for seed production in Nashik, Pune and Ahmednagar districts of Maharashtra state. The questionnaire was prepared to assess their knowledge and practices on seed onion cultivation, general awareness on pesticide recommendations and use, and pollinators exploration for higher seed production. Most of interviewed farmers (50%) allotted 1-2 acres of land for commercial onion seed production from more than 3 years of period. Among several limitations for successful onion seed production 83.33% of respondents faced incidence of pest and diseases in field as a major constraint followed by unavailability of quality seeds (40 %) and labours (20 %). Majority of farmers were unaware of pest identification and preferred pesticides as a priority measure (46.66%) without using recommended pesticides suggested by the CIBRC at higher than recommended dosage (86.66%) for spraying without following the Economic Threshold Level approach (90%). Around 90 % of farmers avoided the use proper protective measures during spraying, 83.33% were unaware about label claim, and harmful effects of pesticides on human health and environment (53.33 %). The majority of farmers (70 %) had knowledge of honeybees but unaware about role in pollination and increasing seed production (73.33%). Present study urged for extension, demonstration and educating the farmer community about scientific production activities, pesticides usage and pollinators role to enhance onion seed production.

Keywords: onion, survey, seed production, constraints, pesticide usage, honey bees

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Introduction:

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Onion (*Allium cepa* L.) is an important export-oriented vegetable among the cultivated alliums in India [1]. India is the second-largest producer of onions in the world after China with 1.79 mha of area and 31.01mMT of production [2]. However, the productivity of onion in the state remains low as 17.32 t/ ha compared to the world average of 19.4 t/ ha [3]. Indian onions are renowned for their pungency, making them a vital component of various dishes globally. In the year 2022-23, India exported 2,525,258.35 metric tons of fresh onions, valued at Rs. 4,522.79 crores or 561.38 USD million (APEDA, 2023). Maharashtra state plays a significant role in India's onion production, contributing 42.73 per cent with a total of 13.30 million tonnes of production [3]. In the year 2022-23, the Maharashtra state produced a total of 6,773.08 thousand metric tonnes of onions on 471.66 thousand hectares of land [3]. Notable, contribution of onion production in Maharashtra, is achieved from Nashik, Ahmednagar and Pune districts, serving both domestic consumption and export purposes [4].

Availability of quality and sufficient seeds at a reasonable time and price are the main constraints in getting a good yield [5]. India requires approximately 9,400 tons of onion seeds each year to cover an area of 11.73 lakh hectares [6]. However, the exact figures on onion seed production and consumption are not available. The organized sector accounts for approximately 40 per cent of the total seed requirement, while farmers use their own seeds to meet the rest [6]. Onion, as a highly cross-pollinated crop due to its protandrous flower nature, attracts various insect pollinators for successful reproduction and seed production [7]. Among these pollinators, honey bees play a dominant role, providing crucial pollination services in seed onion cultivation [7]. The global decline in honey bee populations has raised significant concerns due to its negative impact on both pollination services and quality seed production [7]. While various factors, such as insufficient nutrition, pests, diseases, and the loss of natural habitats, contribute to bee decline, the primary and increasingly evident factor

responsible for bee mortality is the widespread use of pesticides in agricultural practices [8, 9, 10].

The productivity of onion seed crop on the other hand is affected by the attack of various insect pests and diseases causing major reduction in yield triggering economic losses [11]. Therefore, the farmers are insisted for the pesticide application as an inevitable way of pest management. Good agricultural practices recommend the application of only those pesticides that are permitted by regulatory bodies like the CIBRC and initiating the pesticidal spray only at the Economic Threshold Level (ETL) [12]. Under the regulatory control of the Central Insecticides Act of 1968, only certain insecticides are registered and recommended for use on onions in open field conditions to manage the pest complex [13]. Nonetheless, pesticide use at the farm level by farmers varies based on the pest situation, local recommendations, and in many cases, involves the application of higher dosages without adhering to pre-harvest intervals (PHI) [14]. Additionally, the use of non-recommended pesticides is a common occurrence among farmers [14]. Lack of awareness on pesticidal usage among farmers makes them to breach the regulations causing toxicity problems [14]. The indiscriminate use of synthetic pesticides has significant ecological consequences, including the destruction of natural enemies of pests, adverse effects on non-target organisms, the potential for secondary pest outbreaks and destruction of pollinator fauna (Sreelatha and Diwakar, 1997). Additionally, it results in the occurrence of pesticide residues in food and contamination of the environment, which can have harmful impacts not only on human health but also on other forms of life [14].

The watch kept on pesticide usage patterns against crop pests became obligatory not only to safeguard human and environmental health by ensuring food safety, but also to prevent resistance development in insects in coming ages. In light of the above facts, the present study was undertaken to understand the knowledge of farmers on pest and their

symptoms, attitude in following management practices against insect pests, awareness on pesticide usage, pesticide usage pattern and care of pollinator fauna in major onion seed growing districts of Maharashtra state.

2. Materials and methods:

2.1 Location of the study

A roving survey was conducted in the year 2023 across three leading onion producing districts of Maharashtra (19.75.15° N latitude and 75.71.39° E longitude) namely Nashik, Pune and Ahmednagar. The above districts were selected purposively on the basis of major areas under Onion seed production.

2.2 Selection of the respondents

The list of onion seed producers was obtained from TAO, Department of Agriculture, Maharashtra. A total of ten villages were selected from each district. A total of 30 onion seed producers were interviewed during the present study with 10 farmers from each district.

2.3 Nature of information collected

The objectives and scope of the study were explained to farmers for their fair cooperation. Based on the objectives of the present study, a questionnaire format consisting of the following six sections was prepared and data was collected by interviewing the farmers individually using it. Simple statistical tools like frequency and percentage are used to analyse the data.

Section 1: General information about the farmer (farmer name, address, age, education, family particulars).

Section 2: Land cultivation (total cultivable land, area under onion crop, duration of onion cultivation, irrigation method followed & constraints in onion seed production).

Section 3: Pest occurrence in onion field (identification of pests & their symptoms, ETL of pest)

Section 4: Major pesticides used (chemical name, trade name and dosage followed).

Section 5: Pesticide usage pattern (source of information on recommended pesticides, attention towards labels, measurement of pesticides, safety methods followed, dosage of insecticides, type of pesticides used at different crop growth stages, time of spraying, number of sprays, waiting period followed, spray intervals, handling and disposal of pesticide containers)

Section 6: Honey bee pollination (identification of bee species, number of colonies kept for pollination in the field, colony management and awareness)

3. Results and Discussion:

In a survey, a total of thirty farmers provided their responses to a questionnaire framed on pesticide usage pattern and bee management in onion seed crops across three leading districts in onion production (Nashik, Pune and Ahmednagar) of Maharashtra state (**Table 1**).

Table 1. Farmer's responses to questionnaire prepared on various aspects of onion seed production

Sl. No.	Question	Farmer's responses (%)			
	Age of the farmer (%)	Young (<35 years)	Middle (36-45 years)	>46	
		20	53.33	26.66	
	Educational Qualification (%)	Illiterate	Primary	Higher Secondary	Graduation
		16.66	43.33	23.33	16.66
1	Total cultivable land (Acres)	01 to 05	05 to 10	≥ 10	
		23.33	50	26.66	
2	Area under onion crop (Acres)	01 to 02	02 to 04	≥05	
		50.00	33.33	16.67	
3	Since how long are you cultivating onion for seed production? (%)	<3 years	>3 years		
		23.33	76.66		
4	How do you irrigate the crop? (%)	Flooding	Drip	Sprinkler	
		86.66	00.00	13.33	
5	What are the constraints in onion seed production? (%)	a) Quality seed availability			40 %
		b) Pest and disease occurrence			83.33 %
		c) Quality pesticide availability			20 %
		d) Technical knowledge of pesticidal spray			36.66 %
		e) Technical knowledge of pollinators management			53.33 %
		f) Lack of availability of labours on time			20 %
		g) Lack of availability of fertilizers in time			6.66 %
6	Can you identify the different pests of onion and their damaging symptoms? (%)	Yes 83.33 %			No
		Single pest	2-3 pests	≥4 pests	16.66 %
		64	28	8	
7	Major pest occurrence in your seed onion field (%)	Thrips	*H. armigera*	Cutworms	Onion maggot
		86.67	43.33	56.67	16.67

8	Pesticides used against the above pests (%)	Thiamethoxam	Imidacloprid	Emamectin benzoate	Spinosad	Monocrotophos	Cyantraniliprole	Azadirachtin	Dimethoate	Fipronil	Acephate	Quinolphos	Lamda Cyhalothrin	Flubendiamide	Spirotetramat
		10.00	16.67	23.33	20.00	6.67	6.67	16.67	13.33	20.00	3.33	3.33	6.67	6.67	3.33
9	Pesticide application for pest management as (%)	First & preventive option			Only option			Last and curative option							
		46.66			30.00			23.33							
10	Whom do you contact for pesticide recommendation? (%)	Agriculture officer			Dealer			Scientist			Decides my own				
		26.66			56.66			10			6.66				
11	Do you know ETL concept of a pest? (%)	Yes						No							
		10						90							
12	If, yes, do you follow ETL while spraying?	Yes						No							
		0						100							
13	How do you measure the pesticides?	Bottle cap						Approximate measure							
		66.6						33.3							
14	Do you spray the recommended dose of pesticides?	Yes						No							
		6.66						Excess						Less	
								89.28						10.71	
15	Do you think high dose of pesticide gives you a high return?	Yes						No							
		86.66						13.33							
16	Do you wear any protection appliances while spraying?	Yes									No				
		Mouth and nose cover			Gloves			Coat			90				
		6.66			3.33			00							
17	Number of sprays taken on onion crop	1			2			3			>3				
		0.00			0.00			23.33			76.66				

18	Interval of spray	5 days	10 days	15 days	As and when noticed the pest	Pest above ETL
		0.00	6.66	26.66	66.66	0.00
19	Do you spray pesticides during flowering?	Yes			No	
		16.66			83.33	
20	Time of application of pesticides	Morning	Evening		Afternoon	Anytime
		46.66	13.33		30	10
21	Do you have any idea regarding the waiting period?	Yes			No	
		10			90	
22	If yes, do you follow the recommended waiting period?	Yes			No	
		00			100	
23	How do you dispose of the empty pesticide containers?	Buried in soil	Thrown into trash		Leaving randomly in the field	Sell
		0.00	46.66		36.66	16.66
24	Do you use empty pesticide bottles for domestic purposes?	Yes			No	
		63.33			36.66	
25	Do you know anything about label claim?	Yes			No	
		16.67			83.33	
26	Do you have any idea about pesticide residue and its effects?	Yes			No	
		46.67			53.33	
27	Do you take any precautions while spraying to prevent pesticide poisoning?	Yes			No	
		43.33			56.67	
28	Do you know what bees (madhumakki) are?	Yes			No	
		70			30	
29	Do you know about pollination and the role of bees in onion pollination?	Yes			No	
		26.66			73.33	
30	Do you recognize different	Yes			No	

	bee species?	13.33		86.66	
31	On which basis you kept the bee colonies in the field	a) Suggestion by Agriculture officer/ scientist			30.00
		b) By looking at the other farmers			36.66
		c) Suggestion by a farmer friend			13.33
		d) By searching on the internet			20.00
32	Which species of honey bee colonies are kept for pollination?	*A. mellifera*	*A. cerana*	Stingless bee	
		90.00	23.33	6.66	
33	Number of colonies per hectare	1	2	3	≥4
		16.66	20	50	13.33
34	What is your opinion regarding yield increase after keeping the bee colonies in your field?	Yield increased after keeping the colonies	Yield has been reduced	No idea of effect on yield	
		23.33	6.66	70	

3.1 Age distribution and level of education

The examination of socio-economic characteristics among respondent farmers revealed a predominant presence of the middle age group (36-45 years), comprising 53.33 per cent of the surveyed farmers, followed by the old age group category with 26.67 per cent, with the remaining falling into the young age groups (20.00 %) (**Figure 1**). A significant proportion of farmers attained primary education (43.33 %), while 23.33 per cent of the surveyed farmers had their higher secondary education. 16.66 per cent of the farmers obtained their graduation and 16.66 per cent were illiterates (**Figure 2**). Seok et al. [15] reported that aging is associated with positive factors of productivity, such as experience and skills, as well as negative factors such as technical knowledge and creativity. Considering that productivity is closely related to economic growth, the impact of aging on development issues is also not settled. Schultz hypothesis says that education enhances farm productivity in the case of adopters of modern technology [16].

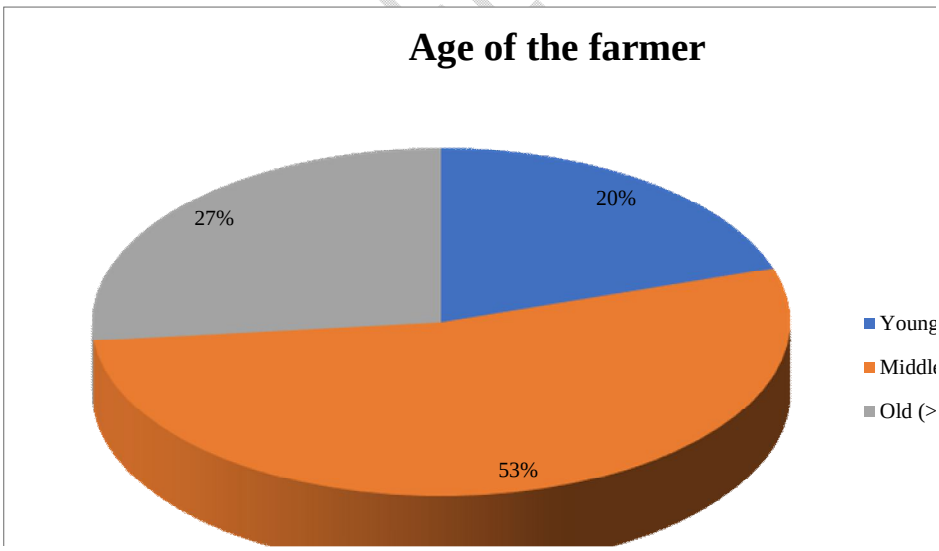


Figure 1. Age distribution of the surveyed farmers

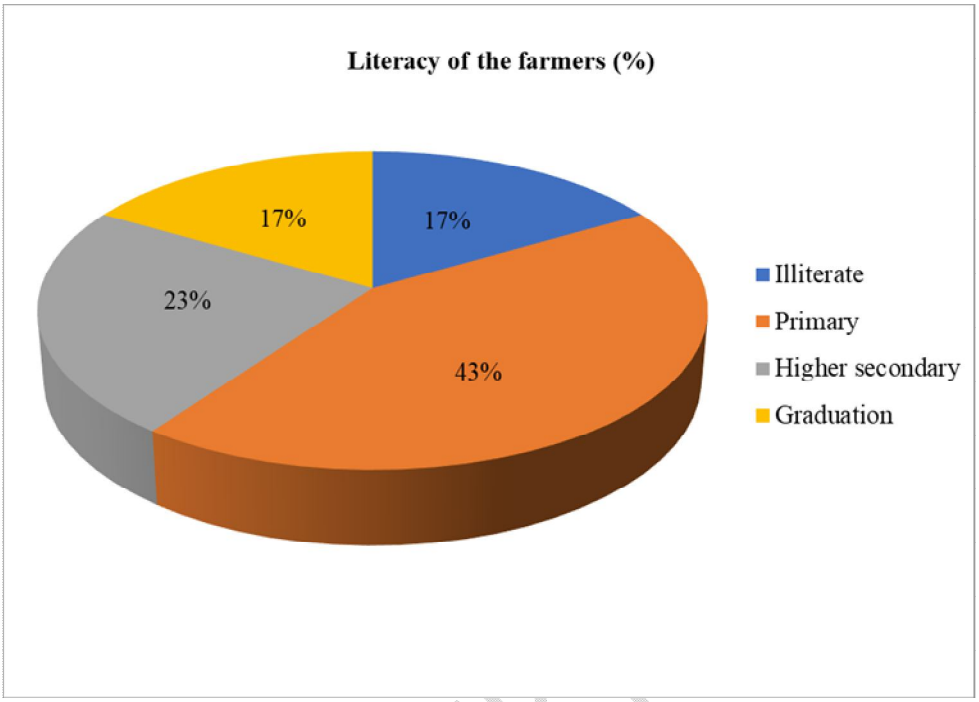


Figure 2. Educational qualification of the surveyed farmers

3.2 Onion cultivation for seed production

The survey revealed that a significant portion of farmers (50 %) possessed cultivable land ranging from 5 to 10 acres, categorizing them under the semi-medium landholding group. Additionally, 26.67 per cent of the surveyed farmers owned more than 10 acres, while 23.33 per cent had 1 to 5 acres of cultivable land (**Figure 3**). In terms of land allocation for onion seed production, 50 per cent of the farmers dedicated only 1 to 2 acres, 33.33 per cent allocated 2 to 4 acres and a mere 16.67 per cent designated more than 5 acres of land for this purpose (**Figure 4**). The majority of farmers (76.66 %) had been engaged in seed production for over 3 years, while 23.33 per cent had initiated onion seed production in recent years (less than 3 years). The farmers were cultivating onion seeds in smaller plots of land for their own domestic consumption, but the income generated from onion seed production is significant [17]. Therefore, encouraging farmers to engage in this activity would be advantageous for

boosting their income [17].

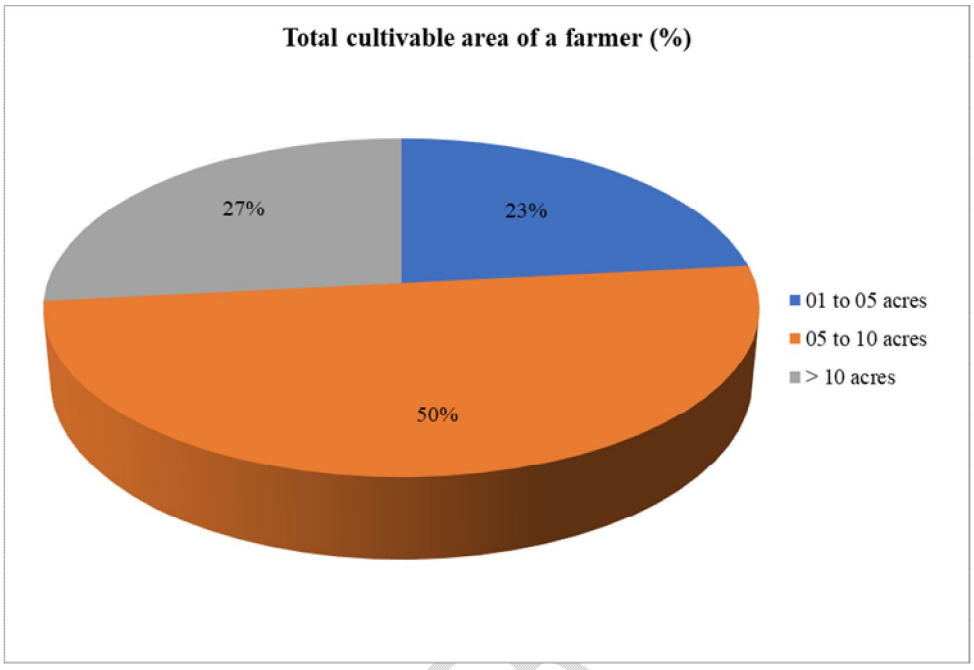


Figure 3. Land holdings of the surveyed farmers

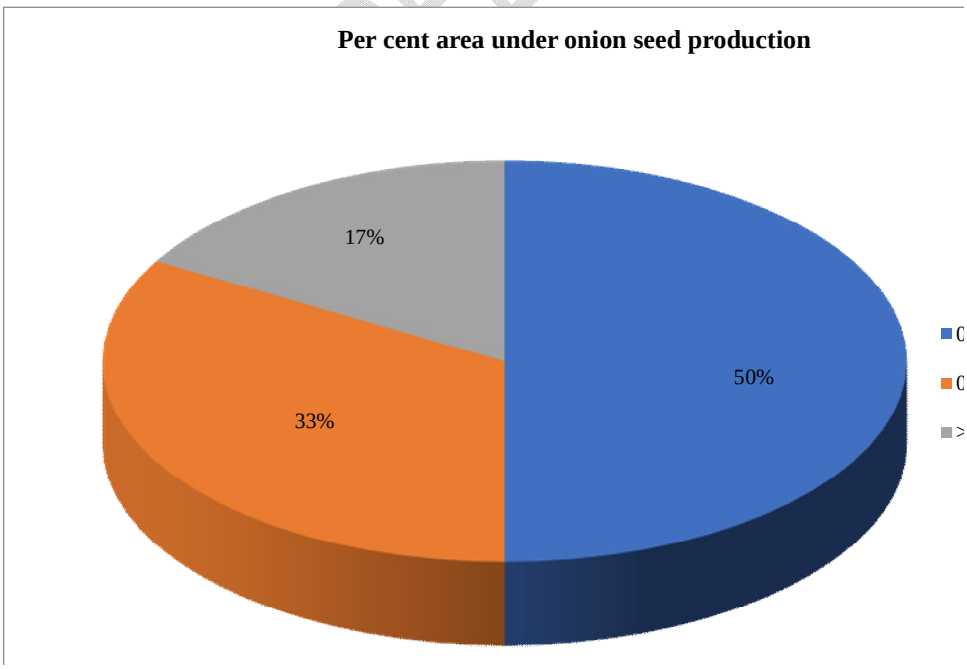


Figure 4. Allocation of land for onion seed production by surveyed farmers

Despite of the poor resource utilization [18], nutrient leaching [19], soil erosion [20], uneven water distribution [18], soil salinization [21] and higher thrips incidence [22], most of the farmers relied on flood irrigation (86.66 %) as a traditional method and 13.33 per cent of the farmers adopted sprinkler irrigation. However, none of the farmers followed drip irrigation system. The choice of flooding method for irrigation was traditional gain while unacceptance of sprinkler and drip methods was due to lack of technical knowledge and technology spread. Fear of clogging problem associated with drip irrigation because of higher salt content in irrigation water also discouraged farmers from adopting this technology [23].

3.3 Constraints faced by farmers in onion seed production

The current study reported that the farmers were confronted with various types of constraints (**Figure 5**) during commercial seed production in the field. Similarly, Jangwad et al. [24] highlighted personal, technological, service and supply, infrastructure, economic, and institutional issues as important constraints in onion seed production. The major limiting factor for efficient onion seed production were the occurrence of pest and diseases (83.33 %). Being a favored host for various insects, the onion has been attacked by number of insect pests including thrips, cutworms, maggots, earwigs and mites. [25] [26] [27] reported invertebrate pests as the major constraint to vegetable production. Karuppaiah et al. [28] enlisted 149 species of insect pests from 97 insect genera that infest onion.

The study also revealed that 53.33 per cent farmers faced a problem with insufficient technical knowledge on pollinators' management. Unavailability of quality bulbs (seeds) for sowing (40 %) was the next major limiting factor in onion seed production. Similar kinds of results were reported by Samantha et al. [29]. [30] confirmed that 71% of the total bulb production of India is used for domestic consumption, 20% goes as waste during storage and

handling, 5% is used for export and 3% for processing whereas only 1% of bulbs are made available for seed production which is limiting the supply of quality bulbs for commercial onion seed production. Size of the bulb and related traits [31], availability of disease and pest-free bulbs [32] and improper storage and handling of bulbs used for seed production [33] may serve as the barriers in efficient onion seed production.

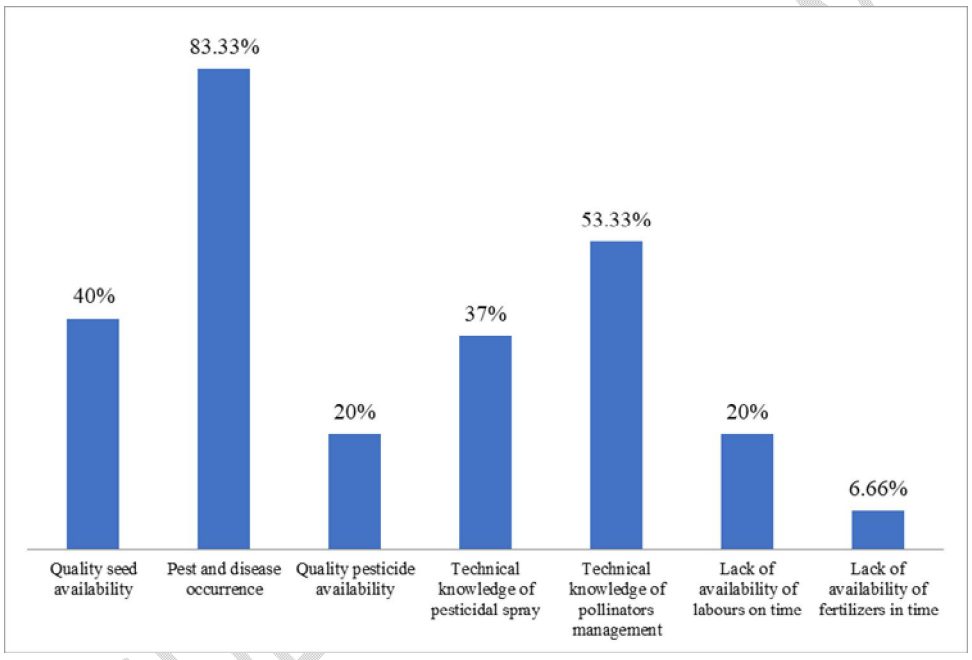


Figure 5. Constraints faced by the surveyed farmers in onion seed production

Present study also found that 20 per cent of farmers responded to unavailability of skilled labors at required time as a limiting factor for onion seed production. Seasonal labor dependency, competing agricultural activities, seasonal migration of agricultural laborers from rural areas to urban centers for non-farm employment can lead to workforce shortages during critical onion seed production periods [34] [35]. High labor costs and the reluctance of laborers to work in remote or rural areas may further limit the availability of labor for onion seed production [36].

Notably present study reported inaccessibility of quality pesticides (20%) as one of the constraints for onion seed production. Availability of counterfeit and substandard pesticides, limited access to genuine products, high costs of pesticides contributed to the above constraint [37] [38]. Addressing these constraints may require comprehensive education and training programs tailored to the needs of Indian farmers, as well as efforts to make technical information more accessible and user-friendly, improved coordination between onion growers and seed producers, as well as investments in disease management and storage practices [27].

Also, present study revealed insufficient technical knowledge on pollinators' management and lack of availability of fertilizers limited 13.33 and 6.66 per cent of farmers respectively for efficient onion seed production.

Limited access to information, adherence to traditional farming practices that may not integrate modern techniques and pest management strategies along with low literacy rates and language barriers coupled with insufficient training and extension services at the grassroots level and financial constraints may collectively contribute to a lack of technical knowledge in pollinator management and pesticide application [39] [40] [41] [42] [43] [44]. The unavailability of the resources like quality bulbs, fertilizers and attack of pests and diseases as a limiting factors for adapting wider onion seed production was reported by [28] and [30]. Similar kind of results were reported by [45][46][47][48][49].

3.4 Occurrence of pests and pesticide usage pattern

The pest occurrence data on cultivated seed onion reported thrips as a major pest with 86.67 per cent share in incidence among all the pests followed by cutworms, *Helicoverpa armigera* and onion maggot with 56.67, 43.33 and 16.67 per cent occurrence, respectively (**Table 1 & 2)**. However, our study conducted at MPKV, Rahuri reported as many as 9 pests on the seed onion (**Table 3**). Although 83.33 per cent of farmers were able

to identify the pest and its symptoms on onion crop, barely 6.6 per cent of them were able to identify and differentiate damage symptoms caused due to more than 4 pests whereas 28 per cent were able to identify symptoms of 2-3 pests and 64 per cent of farmers were able to identify only single pest in field.

Table 2. List of insect pests of onion and their occurrence in the farmer's field

Sl. No.	Known insect pests complex of onion	Pest occurrence		
		Nasik	Ahmednagar	Pune
1	Flea beetle (*Altica* sp.)	-	-	-
2	Dermestid beetle (*Anthrenus jordanicus, A. ocenicus*)	-	-	-
3	Dried fruit beetle (*Carpophilus obsolutus*)	-	-	-
4	Cockchafer (*Melolontha furicicauda*)	-	-	-
5	Ring legged earwig (*Euborellia annulipes*)	-	-	-
6	Pea leaf miner (*Chromatomyia horticola*)	-	-	-
7	Been fly (*Delia platura, D. florilega*)	-	-	-
8	Black onion fly (*Tritoxa flexa*)	-	-	-
9	Pepper fruit fly (*Atherigona orientalis*)	-	-	-
10	Jassid (*Amrasca biguttula biguttula*)	-	-	-
11	Ash leaf hopper (*Macrosteles fascifrons*)	-	-	-
12	Beet army worm (*Spodoptera exigua*)	-	-	-
13	Cutworm (*S. litura*)	Reported	Reported	Reported
14	Cutworm (*Agrotis ipsilon, A. segetum*)	Reported	Reported	Reported
15	Old word boll worm (*Helicoverpa armigera*)	Reported	Reported	Reported
16	Green looper (*Chrysodeixis acuta*)	-	-	-
17	Semilooper (*Trichoplusia orichalcea*)	-	-	-
18	Almond moth (*Ephestia cautella*)	-	-	-
19	Field cricket (*Brachytrupes portentosus*)	-	-	-
20	Grasshopper (*Eucanocephalus* sp.)	-	-	-
21	Thrips (*Thrips tabaci, T. palmi, T. flavus, Caliothrips indicus*)	Reported	Reported	Reported
22	Bulb mite (*Rhizoglyphus robini, R. echinopus*)	-	-	-
23	Red spider mite (*Tetranychus cinnabarinus*)	-	-	-

24	Wheat curl mite (*Aceria tulipae*)	-	-	-

When it comes to pest management, majority of the farmers preferred pesticidal application as a first priority and as a preventive measure (46.66 %). Whereas 30 per cent of farmers opted pesticidal control as the only option for pest management. Barely 23.33 per cent of them wisely preferred to use pesticides as their last and need-based option for pest control. Diversity of insect pests, limited awareness, visual similarities and lack of proper knowledge in pest identification and management are some important reasons for failure in identification of insect pests by farmers at field level [50].

Table 3. List of insect pests recorded at different stages of crop growth during study at MPKV, Rahuri

Sl. No.	Pest occurred	Period of occurrence	Status	Stages	Site of damage	Frequency of occurrence
1	Onion thrips (*Thrips tabaci*)	From Jan.	Pest	Nymphs and Adults	Leaf	Abundant
2	Cut worm (*Agrotis* spp.)	From Dec.	Pest	Larva	Collar region	Abundant
3	Leaf eating caterpillar (*S. litura*)	From Feb.	Pest	Larva	Leaf and umbels	Abundant
4	Bollworm (*Helicoverpa armigera*)	From March	Pest	Larva	Leaf and umbels	Abundant
5	Leaf miner	From Dec.	Pest	Larva	Leaf	Rare
6	Onion maggot	From Dec.	Pest	Larva	Bulb and leaf	Rare
7	Red spider mite	From Feb.	Pest	Nymphs and Adults	Leaf and umbels	Rare
8	Green looper	From Feb.	Pest	Larva	Leaf	Rare
9	Bulb mite	From Dec.	Pest	Nymphs and Adults	Leaf and bulb	Rare

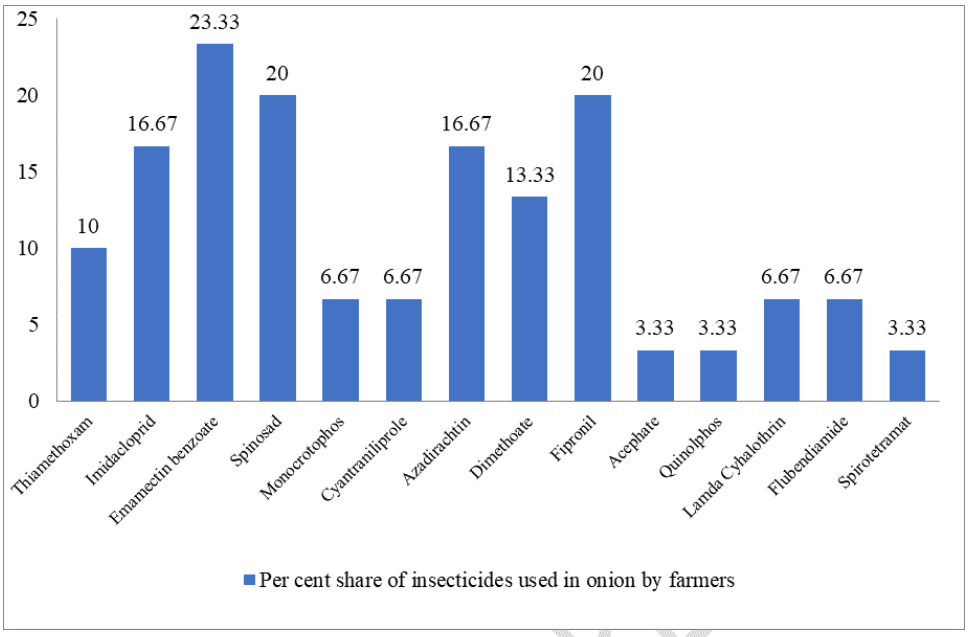


Figure 6. Insecticides used by farmers to tackle the insect pest menace during onion seed production

The results revealed that all the surveyed farmers (100 %) were spraying pesticides at vegetative and late vegetative stages of onion growth, whereas 46.66 % & 16.66 % were at seedling and flowering stages, respectively (**Table 4**). Fourteen different insecticides of diverse modes of action were used to tackle the insect pest menace by farmers (**Table 5**). The pattern of pesticide application was with the highest use of emamectin benzoate around 23.33 per cent followed by fipronil, spinosad, imidacloprid, azadirachtin, dimethoate, and thiamethoxam with 20.00, 20.00, 16.67, 16.67, 13.33 and 10.00 per cent respectively (**Figure 6**).

Table 4. Insecticides application percentage by farmers for pest management at respective onion crop growth stages

Sl. No.	Onion growth stage	Crop duration	Per cent farmers who sprayed insecticides
1	Bulb germination/ sprouting stage	7-10 days	Nill
2	Seedling stage	15-28 days	46.66
3	Vegetative stage	30-34 days	100
4	Late vegetative stage	15-25 days	100

5	Flowering stage	30-48 days	16.66
6	Seed setting stage	20-30 days	Nill
7	Harvesting stage	7-10 days	Nill

Table 5. List of insect pests occurred at different stages of crop growth and pesticides used by farmers for their management

Sl. No.	Crop Growth stage	Insect pest occurred	Pesticides sprayed
1	Bulb germination/ sprouting stage	Onion maggot, cutworms (*Agrotis* spp.)	-
2	Seedling stage	Onion maggot, cutworms (*Agrotis* spp., *S. litura*)	Spirotetramat, Dimethoate, Acephate, Thiamethoxam, Flubendiamide, Quinalphos
3	Vegetative stage	Onion maggot, cutworms (*Agrotis ipsilon, A. segetum, S. litura*), Thrips	Azadirachtin, Lamda Cyhalothrin, Flubendiamide, Cyantraniliprole, Imidacloprid, Fipronil, Monocrotophos, Spinosad
4	Late vegetative stage	Cutworm (*S. litura*), boll worm (*H. armigera)*, Thrips	Azadirachtin, Lamda Cyhalothrin, Flubendiamide, Fipronil, Imidacloprid, Quinalphos, Spinosad
5	Flowering stage	Cutworm (*Spodoptera litura*), boll worm (*H. armigera*)	Azadirachtin, Emamectin benzoate
6	Seed setting stage	Cutworm (*S. litura*), boll worm (*H. armigera*)	
7	Harvesting stage	Cutworm (*S. litura*), boll worm (*H. armigera*)	-

Results also depicted that 56.66 per cent of onion growers were directly relaying on advice of pesticide dealers about insecticide choice for spraying in the field. Only 26.66 and 10 per cent of farmers were contacting agriculture officers and scientists for advisory pesticide spray. Whereas 6.66 per cent of the farmers were using pesticides based on their own knowledge or experience. The limited insecticides are recommended on onion crop by CIBRC [13]. However, farmers were using number of non-recommended insecticides which may lead to ineffectiveness further poor pest management and reduced crop yield [38] (**Table 6**). Therefore, it is essential to promote the use of recommended and registered

pesticides that have been tested and proven effective for onion pest management by CIBRC (**Table 6**), as well as to provide farmers with education and training on proper pesticide selection and application [27].

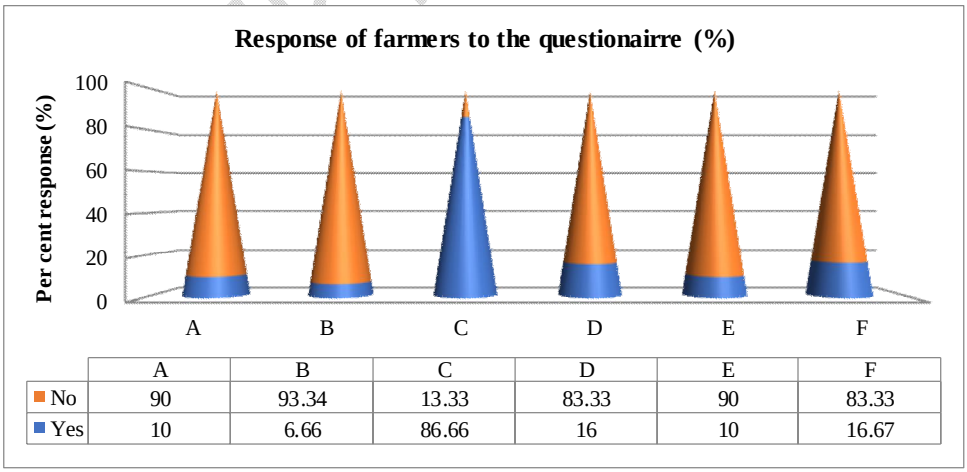
Table 6. Pesticide usage pattern on onion in major onion growing districts of Maharashtra

Recommended pesticides in onion by CIBRC	Formulation dosage (g or ml/ l)	Actual pesticide application by farmers		
		Used pesticides	Recommended dose (g or ml/ l)	Farmers dosage (g or ml/ l)
Chlorpyrifos 20 % EC	10 ml	Quinalphos 25 % EC	Not recommended	1- 2 ml
Deltamethrin 11 % w/w EC	0.3 ml	Cyantraniliprole 10.26 % OD	Not recommended	1-2 ml
Dimethoate 30 % EC	1.32 ml	Spinosad 45 % SC	Not recommended	0.5- 1 ml
Fipronil 80 % WG	0.15 g	Azadirachtin 01.00 % EC (10000 PPM)	Not recommended	2-2.5 ml
Lambda-cyhalothrin 05 % EC	1 ml	Lambda-cyhalothrin 04.90 % CS	Not recommended	0.5-1ml
Oxydemeton-methyl 25 % EC	2.4 ml	Lambda-cyhalothrin 04.90 % CS	Not recommended	0.2-0.5 ml
Tolfenpyrad 15 % EC	2 ml	Fipronil 80 % WG	0.15 g	0.5-0.6 g
		Fipronil 18.87 % w/w SC	Not recommended	0.5-1 ml
Verticillium lecanii 3.0 % AS, (strain: Accession No. MCC-1127, Strain No. MPKV / Biocontrol/ RVN/ VL-01	4-5 g	Imidacloprid 70 % WG	Not recommended	0.3-0.5 g
-	-	Acephate 75 % SP	Not recommended	2-2.5 g
-	-	Dimethoate 30 % EC	1.32 ml	1-1.5 ml
-	-	Spirotetramat 15.31 % w/w OD	Not recommended	0.5-1 g
-	-	Thiamethoxam 75 % w/w SG	Not recommended	0.4-0.5 g
-	-	Monocrotophos 36 % SL	Not recommended	1-2 ml
-	-	Emamectin benzoate 05 % SG	Not recommended	0.5-1 g

3.5 Farmers' knowledge and perception on pesticide usage and their effects

Several questions were asked to the surveyed farmers to understand their technical

knowledge and awareness on pesticide usage and its effects (**Figure 7**). The results indicated that 90 per cent of the farmers had no any idea regarding ETL of a pest. Although remaining 10 per cent were aware about ETL, they never followed ETL based spraying of the insecticides in onion field. 66.66 per cent of the farmers preferred to spray the insecticides as and when the insect pests were noticed whereas 26.66 per cent were spraying at 15 days and 6.66 percent at 10 days of interval. The measurement of insecticides dosage was done by using container cap (66.6 %) and notably 33.3 per cent of farmers were directly adding pesticides dosage into spray fluid without proper measurement. The survey also depicted that hardly 6.66 per cent of farmers followed the recommended dosage of insecticides while spraying, whereas 93.33 per cent of the farmers deviated from the recommended dose of spraying, out of which 89.28 per cent were spraying the high dose than recommended by thinking that high doses of pesticides give them high returns and 10.71 per cent of the farmers used lower doses of pesticides. The majority of the farmers took more than 3 sprays of insecticides (76.66 %) on onion crop throughout the complete crop growth period while a few (23.33%) were taking only 3 sprays.



	A	B	C	D	E	F
No	90	93.34	13.33	83.33	90	83.33
Yes	10	6.66	86.66	16	10	16.67

A. Do you know ETL concept of a pest? **B.** Do you spray the recommended dose of pesticides? **C.** Do you think high dose of pesticide gives you a high return? **D.** Do you spray

pesticides during flowering? **E.** Do you have any idea regarding the waiting period? **F.** Do you know anything about label claim?)

Figure 7. Response of the farmers to various queries on pesticide usage patterns

The basic knowledge regarding the pest management and pesticidal usage was lacking among the farmers surveyed in the present study. Many of the farmers had no idea regarding ETL, importance of accurate dosage measurement of pesticides and were found to be spraying high dose of insecticides without knowing its adverse effect. The farmers thought that higher doses will give them high income returns and were spraying without following proper package of practices. Several negative consequences including financial loss, pesticide resistance, environmental impact, health concerns are needed to be considered [51][52][53][54]. Considering the high frequency of spraying reported by farmers, economic injury levels and economic thresholds are required to guide farmers on decision making in pest management and training on efficient and safe use of pesticides [27]. Rather than deciding to apply pesticides when the presence of a pest or damage symptoms has been observed, better guidance on calendar spray schedule is needed for farmers to reduce the risks of pesticide residues, pest resistance, pest resurgence and adverse effects on natural enemies [27].

3.6 The status of protective devices utilization while pesticide application

Surveyed results surprisingly found that 90 per cent of the farmers were conducting the spraying operation in their field without any protection measures. However, hardly 6.66 per cent of farmers were covering their mouth and nose and 3.33 per cent used gloves as protectives during pesticidal applications. None of the farmers used the complete protection kit while spraying. Most of the farmers preferred spraying of pesticides in morning time (46.66 %) followed by afternoon (30 %), evening (13.33 %) and few farmers were spraying irrespective of the time (10 %).

Using of protective equipments during spray operation is mandatory in the area, to

minimize exposure to pesticides during mixing and spraying time [55]. Present study would suggest the need of programs to increase awareness of farm safety and occupational hazards which would be an effective way of convincing farmers to use protective equipment. Lightest wind hours (morning and evening hours) are best suitable for pesticidal application as it reduces severe drifting and toxicity to non-target organisms [56] than the rest of the day. Therefore, there is an urgent call to provide educational, demonstrative and other intervention efforts that may have a positive impact on protective equipment use, best spraying time and the precaution needed to be taken before spraying [57][58].

3.7 Environmental effect of pesticides contamination

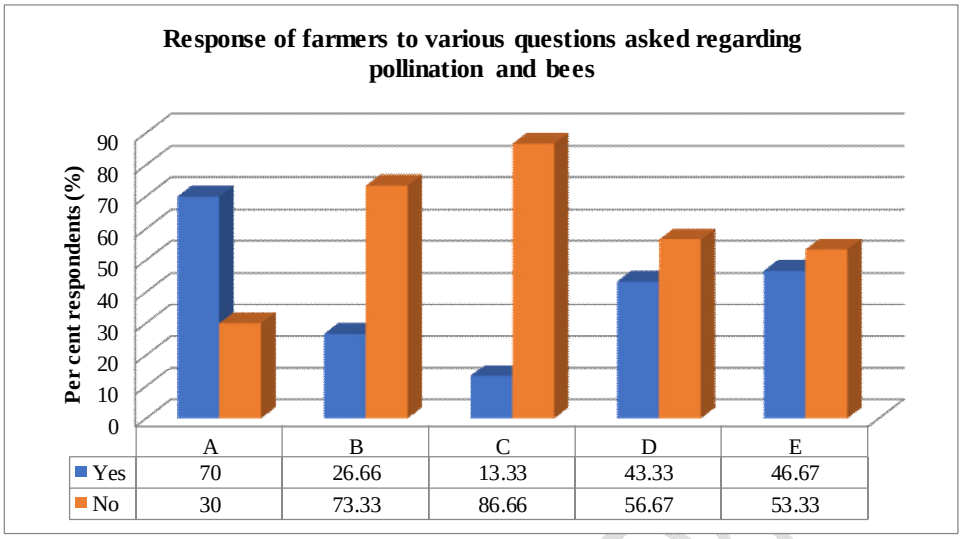
The majority of the respondents had no idea of the waiting period after the insecticide application. 10 per cent of the farmers knew about the waiting period but failed to follow the same (100 %). After the spray, 46.66 per cent of the farmers discarded the empty containers of pesticides to trash, 36.66 per cent of farmers randomly left them in the field and 16.66 per cent of farmers sold the empty containers. None of the farmer buried the used pesticide container in the earth. Majority of the farmers (83.33 %) were unaware of the label claim of pesticides and nearly half of the surveyed farmers had no idea about pesticide residue and its effects (53.33 %).

The interviewed farmers were having a poor knowledge regarding pesticidal management and environmental effect of pesticides contamination. There was always little time lag between pesticide application and regular field visits in onion. However, the waiting period is a crucial component of pesticide safety to prevent acute and chronic health effects associated with pesticide exposure and is essential for protecting the health and well-being of agricultural workers, bystanders, and the environment [59]. The respondents were not having the proper idea of label claim and many were not disposing the empty pesticide cans in a proper way and were using the cans for domestic purposes, sometimes sold or used

as storage containers for other materials such as fuel, other chemicals, and sometimes even food or water. However, dumping the empty containers in the field or throwing them near or into irrigation canals and streams or their domestic use is a totally unsafe practice and has been reported as a major problem that may pose a threat to surface water or groundwater and pose a hazard to humans, domestic animals, and wildlife [60]. Therefore, there is an urgent call to educate the farmers with respect to the above aspects.

3.8 Technical knowledge of pollinators in onion seed production

The survey also highlighted the knowledge of farmers on the role of pollinators in onion seed production (**Figure 8**). Results showed that 70 per cent of the farmers were aware about what bees (madhumakki) are however only 26.66 per cent of them had idea about the role of bees in onion pollination enhancing onion seed productivity. About technical knowledge to identify different bee species, only 13.33 per cent of the farmers were skilled to recognize different bee species visiting onion umbels. Further it was found that 36.33 per cent of farmers were motivated to keep bee colonies in onion fields for enhancing pollination by looking towards fellow farmers. However, 30 per cent of the farmers kept the bee colonies in the field after suggestion from Agriculture Officer/ scientist, 20 per cent of the farmers were inspired through internet source and 13.33 per cent of the farmers kept the bee hives in their field by suggestion from a farmer friend.



	A	B	C	D	E
Yes	70	26.66	13.33	43.33	46.67
No	30	73.33	86.66	56.67	53.33

(**A.** Do you know what bees (madhumakki) are? **B.** Do you know about pollination and the role of bees in onion pollination? **C.** Do you recognize different bee species? **D.** Do you take any precautions while spraying to prevent pesticide poisoning? **E.** Do you have any idea about pesticide residue and its effects?)

Figure 8. Response of farmers to various queries regarding pollination and pollinators

Farmers, who set up their fields indicated a strong preference for *Apis mellifera* colonies in pollination services for effective onion seed set, accounted for 90 per cent of the overall preference. Using *A. mellifera* colonies must be the popular practice adopted by seed growers due to the easy availability, rearing methods and compatibility in transportation of *A. mellifera* bees [61]. Whereas the preference for *Apis cerana indica* and stingless bee colonies for pollination activity was 10.00 and 3.33 per cent, respectively. However, *A. mellifera* is the weak pollinator of onion due to its susceptibility to higher potassium content in onion flower nectar resulted in low bee visits because [62]. *A. cerana indica* due to their reduced sensitiveness for potassium content of nectar and pesticides [63] and stingless bee's due to their preference for smaller flowers [64] are the better pollinators of onion flowers and can be promoted in onion fields.

A total of 3- 9 strong colonies of *Apis mellifera* and *Apis cerana indica* per hectare

are recommended for efficient pollination of the insect pollinated crops [65]. [66] recommended 10 colonies of stingless bee per hectare in onion crop which recorded highest yield of 8.15q/ ha in her experiment. However, the survey indicated that 56.67 per cent of farmers kept 3 colonies of honey bees per hectare for pollination followed by 16.67, 13.33 and 13.33 per cent farmers kept 2, 1 and 4 colonies per hectare respectively for efficient pollination. Survey also depicted that 83.33 per cent farmers were not spraying any pesticides during flowering stage of the onion however a small group was spraying even during flowering (16.66 %) (**Table 1 & 5**). Regarding the influence of pollinators on yield, 23.33 per cent of the farmers opinioned that yield has increased after keeping the bee colonies in field during flowering while 6.66 per cent of respondents reported reduction in the yield and 70 per cent of farmers had no idea regarding increase or decrease in the yield. Therefore, conducting the training programs and workshops, demonstration at farm levels, farmers's field schools and extension services will be effective in promoting the farmers for efficient use of artificial bee colonies in enhanced onion seed production ultimately conserving bees and maintaining biodiversity as well [67][68][69][70].

Conclusion:

The present survey study briefly highlighted an assessment of pesticide usage pattern in onion ecosystem of major onion growing districts of Maharashtra state. The majority of onion seed growers owned semi-medium cultivable land holdings but they allotted very small land for commercial onion seed production as a cause of various technical, personal, technological, environmental, pest and diseases, labor scarcity and market related constraints in production process. Lack of technical knowledge in identification of pest and diseases and their symptoms made farmers to follow needless pesticidal spray without following ETL approach to manage the menace. Furthermore, most of the farmers relied on non-recommended pesticides, taking higher dosage of chemicals and without taking proper care

during spraying causing danger to human health as well as environment. There was huge scarcity of information on choice of pesticides, label claim, pesticide residues, disposal of pesticide containers and environmental damage through performing unscientific production activities in field. Although most of farmers were aware about honey bee pollinators, many of them failed to skillfully use artificial bee colonies for enhanced onion seed production. Finally, the study concludes that proper extension work, on-field demonstrations, time to time advisory, easy availability of technicians would help to improve knowledge gap leading to scientific commercial cultivation of seed onion to improve economics of farmers families.

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