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Population dynamics of insect pests of castor

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Abstract
Studies on population dynamics of insect pests of castor and their natural enemies were carried out at Zonal Agricultural Research Station, UAS, GKVK, Bangalore. A total of twenty insect species belonging to twelve families and five orders were observed during this study. Leafhopper activity started at seedling stage with peak incidence during 29th Standard Meteorological Week (SMW) whereas, leaf miner, tussock caterpillar, thrips, castor semilooper, castor spiny caterpillar and whitefly reached their peak populations during 27th, 31st, 33rd and 35th SMW, respectively. Capsule borer activity peaked during 29th SMW at capsule development stage. All the pests were negatively correlated with the maximum temperature, except for leaf miner and tussock caterpillar. The results of influence of minimum temp. were similar to that of max. temp., except for whitely population. The pests showed positive correlation with min. and max. relative humidity except leaf miner which was negatively correlated with min. RH and whitefly and tussock caterpillar whose population decreased with increasing max. RH. Sun shine hours favored the development of leaf miner but no other pests. Rainfall influenced leafhopper, thrips and castor semilooper negatively.

Keywords: Castor, population, standard meteorological week, peak incidence, temperature

Introduction
Castor, *Ricinus communis* Linnaeus (Euphorbiaceae) is one of the important annual non-edible oilseed rainfed crops cultivated mostly in arid and semi-arid regions. Castor seeds contain up 42 percent extractable oil which has multiple industrial, agricultural, domestic and medical uses (Agyenim-Boateng *et al.*, 2018) [1]. India leads the globe in total castor seed production (FAO, 2020) [7] with 70 percent and 87 percent of world area and production, respectively followed by Brazil and China (Agyenim-Boateng *et al.*, 2018) [1]. India has the production of 1646.96 thousand tonnes from 887.50 thousand hectares area and productivity of 1,856 Kg/ha. In India, Gujarat, Rajasthan and Andhra Pradesh are the major contributing states (Anon., 2021) [5]. Insect pests and diseases together cause more than 25 percent yield losses, among which around 50 insect and mite species account for yield loss of upto 40–89 percent. Application of insecticides having broad spectrum activity pose a threat to natural enemies which may result in pest resurgence and also affect environment (Singh *et al.*, 2020) [19].
Correlation study of temperature, RH, *etc* with the pest infestation contribute for effective pest management through forecasting of pest population outbreaks as they influence the occurrence and extent of damage caused by these pests (Karan, 2014) [10]. Prophylactic control measures encompassing the knowledge on seasonal occurrence and period of peak activity of pests and their respective natural enemies can reduce the curative management practices to certain extent (Singh *et al.*, 2020) [19]. Thus, the current study was proposed to study the occurrence of insect pests of castor which play a crucial role in assuring environmental safety.

Material and Methods
The current investigation to study the population dynamics of insect pests of castor was carried out at Zonal Agricultural Research Station (ZARS), UAS, GKVK, Bangalore during 2021-22, which comes under Eastern Dry Zone of Karnataka. The meteorological data that prevailed during the period of study was collected at UAS, Bangalore.
The population fluctuation studies were carried out on the hybrid DCH-177, sown on 12th May 2022. Sowing was taken up in an area of 100 sq. meter with the spacing of 60*90 cm. Experimental plot was maintained with standard agronomic practices (Anon., 2019) [3] except plant protection measures to maintain optimum plant population.

Observations were recorded from ten randomly selected plants at different phenological (growth) stages of the crop from germination to harvest (Table 1) at fortnightly intervals as suggested by previous researchers, Laxman *et al*. (2017) [11]. Insect pests and natural enemies were correlated with weather parameters like minimum and maximum temperatures, morning and evening relative humidity (RH), rainfall and sunshine hours (SSH).

Table 1: Different growth stages of castor crop

Sl. No.	Day After Sowing	Stage
1.	8-10	Germination
2.	10-25	Seedling
3.	26-60	Vegetative
4.	61-100	Capsule formation
5.	>100	Maturity

(Hegde, 1996) [8]

Observations

i) Leafhoppers: Leafhopper counts (nymphs and adults) were recorded on 3 randomly selected leaves in each plant, one leaf from top (excluding two topmost leaves), middle (medium maturity) and bottom (leaving one or two bottom most leaves) on the main shoot. Population was recorded as number of leafhoppers per three leaves per plant. Further, the percent leaf area showing hopper burn injury per plant was recorded as average of three leaves of the plant (Table 2).

Table 2: Hopper burn grades based on percent leaf area damage (0 to 4 scale)

Hopper burn grades	Percent hopper burn	Inference
0	No injury	Highly Resistant
1	Upto 10	Resistant
2	11 to 25	Moderately Resistant
3	26 to 50	Susceptible

(Anon., 2020) [4]

ii) Whitefly: The absolute population of whiteflies (nymphs and adults) was recorded from 3 leaves/plant (Table 3) similar to leafhoppers.

Table 3: Scoring based on number of whiteflies present on leaves (0 to 5 scale)

Score	Whitefly population
0	No nymphs & pupae
1.	1 to 50 nymphs & pupae
2.	51 to 100 nymphs & pupae
3.	101 to 200 nymphs & pupae
4.	201 to 500 nymphs & pupae
5.	More than 500 nymphs & pupae and honey dew secretion with black sooty mold

(Anon., 2020) [4]

iii) Thrips: Absolute population of thrips per spike was recorded by beating the spikes on a white or black cardboard sheet and counting the number of adults and nymphs of thrips.

iv) Defoliators: For defoliators like semiloopers, ash weevils, castor spiny caterpillar, grasshoppers, etc., absolute numbers of damaging stages per plant was recorded and the extent of damage was reported based on visual observations (Table 4).

Percent leaf area infested/plant = visual score of leaf area damaged

Table 4: Percent leaf damage caused by defoliators (0 to 4 scale)

Score	Percent Defoliation	Inference
0	No damage	Highly Resistant
1	<25	Resistant
2	26 to 50	Moderately Resistant
3	51 to 75	Susceptible
4	76 to 100	Highly Susceptible

(Anon., 2020) [4]

v) Castor shoot and capsule borer: Castor shoot and capsule borer population was recorded as the number of capsules infested among total number of capsules observed per plant and taken as percentage infestation as given below (Table 5).

$$\text{Percent infestation of capsules (per plant)} = \frac{\text{No. of capsules infested}}{\text{Total number of capsules observed}} \times 100$$

Table 5: Percent capsule damage by shoot and capsule borer (0 to 3 scale)

Score	Percent capsules damaged	Inference
0	0 to10	Resistant
1	> 10 to 20	Moderately resistance
2	> 20 to 40	Moderately susceptible
3	> 40	Susceptible

(Hegde, 2009) [9]

vi) Leaf miner: The leaf miner infestation was taken as percentage leaf infestation per plant as the number of leaves mined among the total leaves per plant as follows (Table 6).

$$\text{Percent leaf infestation (per plant)} = \frac{\text{No. of leaves infested}}{\text{Total number of leaves in plant}} \times 100$$

Table 6: Scoring for leaf miner infestation in castor (0 to 3 scale)

Score	Leaf miner infestation (%)	Inference
0	0 to10	Resistant
1	> 10 to 25	Moderately resistance
2	> 25 to 50	Moderately susceptible
3	> 50	Susceptible

(Hegde, 2009) [9]

For observations on natural enemies of pests of castor, the immature stages i.e., egg, larva and pupa of pests were collected from the field and were reared and got identified by the taxonomists.

Results and Discussion

Knowledge on seasonal incidence of these pests and their natural enemies is one among the crucial components of integrated pest management. The results of the present investigation revealed that the crop harboured various groups of insect pests of 20 species belonging to 12 families under five orders (Table 7) and their respective natural enemies were observed. Throughout the cropping season, leafhoppers, whiteflies and thrips were the more prevalently occurring sucking pests. Defoliators like castor semilooper, castor spiny caterpillar, tussock caterpillar, leaf miner and ash weevils were frequently observed during the experiment.

Table 7: List of insect pests occurred on castor crop during *Kharif*, 2022

Sl. No.	Common name	Scientific name	Family	Order
Sap feeders				
1.	Leaf hopper	*Empoasca terminalis* Distant, 1918 *Empoasca distinguenda* Paoli, 1932 *Empoasca kerri* Singh-Pruthi, 1940 *Empoasca motti* Singh-Pruthi, 1940 *Jacobiasca furcostylus* (Ramakrishnan & Menon, 1972) *Empoasca spirosa* Dworakowska & Viraktamath, 1979 *Empoasca* sp.	Cicadellidae	Hemiptera
2.	Whitefly	*Trialeurodes ricini* (Misra)	Aleyrodidae	Hemiptera
3.	Green stink bug	*Nezara viridula* (Linnaeus)	Pentatomidae	Hemiptera
4.	Thrips	*Scirtothrips dorsalis* Hood 1919	Thripidae	Thysanoptera
Defoliators				
1.	Ash weevil	*Myllocerus subfasciatus* Guerin-Meneville *Myllocerus viridanus* (Fabricius)	Curculionidae	Coleoptera
2.	Black looper	*Hyposidra talaca* (Walker, 1860)	Geometridae	Lepidoptera
3.	Castor spiny caterpillar	*Ariadne merione* (Cramer, [1777])	Nymphalidae	Lepidoptera
4.	Castor semilooper	*Acanthodelta janata* Linnaeus, 1758	Noctuidae	Lepidoptera
5.	Gram pod borer	*Helicoverpa armigera* Hübner	Noctuidae	Lepidoptera
6.	Flea beetle	*Monolepta signata* (Olivier)	Chrysomelidae	Coleoptera
7.	Tussock caterpillar	*Olene mendosa* Hübner, 1823	Erebidae	Lepidoptera
8.	Leaf miner	*Liriomyza trifolii* (Burgess, 1880)	Agromyzidae	Diptera
	Shoot and capsule borer	*Conogethes punctiferalis* (Guenée, 1854)	Pyralidae	Lepidoptera

Insect pests

A total of seven leafhopper species belonging to two genera namely, *Empoasca* and *Jacobiasca* were observed (Table 7). The pest incidence started at 25th SMW with a population of 6.30 leafhoppers/3 leaves/plant coinciding with the beginning of vegetative stage *i.e.*, at 30 days after germination which is on par with findings of Shilpakala (2014) [18] where the population first appeared at 15 days after germination. Peak population (14.40 leafhoppers/3 leaves/plant) was observed during 29th SMW (July) which is the beginning of capsule formation stage and is on par to the results of Akashe *et al*. (2015) [2] where the peak activity was observed during August to September. Later the population decreased gradually towards the crop maturity (Table 8). The correlation studies revealed that the weather parameters did not significantly influence the occurrence of leafhoppers on castor crop, which is in contrast with the results of Ranga *et al*. (2022) [16] where, significant influence of evening RH on the pest was recorded. The population was negatively influenced by maximum temperature, minimum temperature, rainfall and SSH which is in line with Ranganatha *et al*. (2021) [17]. Morning and evening RH influenced the pest population positively (Table 9) which is similar to the observations of Patel *et al*. (2015) [15] where morning RH had non-significant positive correlation but evening RH had significant negative correlation. Multiple regression equations developed for each pest are given in the Table 10. The population of whitefly, *Trialeurodes ricini* started to appear at 31st SMW (July) with 1.83 whiteflies/3 leaves/plant during capsule formation stage. The peak population of 5.29 whiteflies/3 leaves/plant was observed during 35th SMW when the crop was at maturity stage later reduced gradually to zero towards the end of the maturity stage which is on par with findings of Akashe *et al*. (2015) [2] where the peak activity was observed during August to September. A non-significant relationship was observed between whitefly population and the weather parameters under consideration. Maximum temperature SSH and morning RH had negative impact which is in line with Patel *et al*. (2015) [15] where significant and negative relationship was recorded between evening RH and whitefly population. Minimum temperature, evening RH and rainfall had positive impact on the occurrence of the pest.

The population of Thrips, *Scirtothrips dorsalis* (1.78/ spike) was first observed during 33rd SMW (August) at the end of capsule formation stage which is similar to the findings of Akashe *et al*. (2015) [2] where the peak activity was observed from August to September. There after the pest incidence was not observed. In spite of the positive correlation with evening / morning RH, all other factors had negative effect on its population which is in contrary with the results of Patel *et al*. (2015) [15], where they confirmed that the thrips population has significant and negative correlation with morning and evening RH.

Castor semilooper, *Acanthodelta Janata* population occurred twice during the crop period. Once during 25th SMW (June) *i.e.*, at the beginning of vegetative stage with 0.10 larvae/ plant which is stage is on par with observations of Shilpakala (2014) [18] where the results showed that the pest appeared 15 days after germination. Another time during 33rd SMW (August) which was during capsule formation stage with a peak population of 0.22 larvae/ plant which is in line with Ranga *et al*. (2022) [16]; Akashe *et al*. (2015) [2] where they noticed the peak activity of the pest during August-September. The pest was negatively but non-significantly influenced by SSH, rainfall and minimum and maximum temperature which is contrast to findings of Ranganatha *et al*. (2021) [17] where maximum temperature had influenced the pest positively but similar to Narayanamma and Reddy (2015) [13] where rainfall had negative impact. Positive and non-significant relationship was found between morning and evening RH and pest population. Castor spiny caterpillar, *Ariadne merione l*arvae started to appear during 29th SMW (60 days after germination) at capsule formation stage with the population of 1.20 larvae/plant which is on par with the findings of Shilpakala (2014) [18] where the appearance of pest started 50 days after germination. It reached the peak value of 1.50 larvae/ plant at 31st SMW (capsule formation stage). Towards the end of the cropping season, the incidence of pest became nil. A non-significant negative correlation was found between occurrence of castor spiny caterpillar and max. and min. temp. and SSH and a non-significant positive correlation was observed with evening and morning RH and rainfall.

Tussock caterpillar, *Olene mendosa* started appearing at 31st SMW (Aug.) with a peak population of 0.67 larvae/ plant during capsule formation stage of the crop followed by decrease in its incidence to 0.11 larvae/ plant during 33rd SMW (Aug.) at the end of capsule formation. Population of tussock caterpillar was not significantly influenced by any of the weather parameters. Morning RH and SSH affected the pest negatively while it was positively influenced by maximum and minimum temperature, evening RH and rainfall.

Leaf miner, *Liriomyza trifolii* infestation started at 23rd SMW during seedling stage with 2.71 percent leaf damage and increased gradually till 27th SMW and reached the peak damage (7.46 % leaf damage) during vegetative stage which is in line with the findings of Makvana *et al*. (2004) [12] and Shilpakala (2014) [18] where they noticed that the pest infestation started with germination of cotyledonary leaves and at 15 days after germination respectively. Later, the population reduced gradually and ceased towards the crop maturity (39th SMW). Leaf miner population was positively correlated with morning and evening RH, rainfall and wind speed and negatively by maximum temperature in a study conducted by Ranganatha *et al*. (2021) [17] which is similar to present study as long as evening RH and rainfall are considered but not the morning RH and maximum temperature which influenced the pest negatively and positively respectively.

Table 8: Insect pests and natural enemies observed on castor during *Kharif*, 2022

SMW	Leaf hopper (Per 3 leaves/ plant	Whitefly (Per 3 leaves/ plant	Thrips (Per spike)	Castor semilooper (larvae/ plant)	Castor spiny caterpillar (larvae/ plant)	Tussock caterpillar (larvae/ plant)	Leaf miner (% leaves mined/ plant	Ash weevil (Adults/ plant)	Capsule borer (% capsules bored)	Spiders (Per plant)
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00	2.71	0.00	0.00	0.00
25	6.30	0.00	0.00	0.10	0.00	0.00	5.52	0.40	0.00	0.00
27	10.70	0.00	0.00	0.00	0.00	0.00	7.46	1.10	0.00	0.20
29	14.40	0.00	0.00	0.00	1.20	0.00	3.40	0.80	6.21	0.00
31	3.00	1.83	0.00	0.00	1.50	0.67	2.94	0.50	2.99	0.00
33	1.89	0.11	1.78	0.22	0.11	0.11	1.24	0.11	0.00	0.22
35	3.71	5.29	0.00	0.00	0.43	0.00	0.15	0.57	1.75	0.29
37	0.40	1.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
39	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mean	4.05	0.82	0.18	0.03	0.32	0.08	2.34	0.35	1.19	0.07

*SMW- Standard Meteorological Week; Values are average of 10 plants

Ash weevil, *Myllocerus* sp. first appeared at 25th SMW (vegetative stage) with a population of 0.40 adults/plant and peak population was observed at 27th SMW (1.10 adults/ plant). A non-significant negative correlation was found between ash weevil occurrence and max. and min. temp. and SSH and a non-significant positive correlation with evening and morning RH and rainfall.

Table 9: Correlation between insect pests of castor with weather parameters during *Kharif* 2022

Insect pests	Mean pest population	Maximum temperature (°C)	Minimum temperature (°C)	Evening RH (%)	Morning RH (%)	Sun Shine Hours	Rainfall (mm)
Leaf hopper	4.05	-0.46	-0.37	0.42	0.56	-0.55	-0.01
Whitefly	0.82	-0.04	0.22	0.57	-0.11	-0.39	0.27
Leaf miner	2.34	0.12	0.05	-0.05	0.12	0.02	0.03
Capsule borer	1.19	-0.42	-0.34	0.58	0.36	-0.60	0.14
Thrips	0.18	-0.24	-0.16	0.25	0.24	-0.10	-0.33
Ash weevil	0.35	-0.33	-0.20	0.48	0.45	-0.58	0.05
Castor spiny caterpillar	0.32	-0.21	-0.15	0.57	0.23	-0.53	0.32
Castor semilooper	0.03	-0.16	-0.09	0.18	0.22	-0.02	-0.12
Tussock caterpillar	0.08	0.14	0.11	0.28	-0.07	-0.14	0.32

RH-Relative Humidity; Values are mean of 10 observations

Table 10: Regression equations indicating relationship between insect pest of castor and weather parameters

Insect pests	Regression equation	R^2 value
Leaf hopper	$Y = -232.00 + 5.74 X_1 - 3.54 X_2 + 0.60 X_3 + 1.60 X_4 - 1.11 X_5 - 0.19 X_6$	0.49
Whitefly	$Y = 23.84 - 1.14 X_1 + 1.65 X_2 + 0.28 X_3 - 0.73 X_4 - 0.95 X_5 + 0.06 X_6$	0.88
Leaf miner	$Y = -299.86 + 4.71 X_1 + 0.52 X_2 + 0.73 X_3 + 1.57 X_4 + 0.75 X_5 - 0.16 X_6$	0.46
Capsule borer	$Y = 104.43 + 0.39 X_1 - 3.37 X_2 - 0.19 X_3 - 0.45 X_4 - 1.49 X_5 - 0.11 X_6$	0.54
Thrips	$Y = -93.99 - 0.06 X_1 + 1.83 X_2 + 0.44 X_3 + 0.33 X_4 + 0.69 X_5 - 0.07 X_6$	0.70
Ash weevil	$Y = -22.70 + 0.60 X_1 - 0.15 X_2 + 0.04 X_3 + 0.11 X_4 - 0.22 X_5 - 0.03 X_6$	0.59
Castor spiny caterpillar	$Y = 7.29 + 0.48 X_1 - 0.92 X_2 + 0.02 X_3 - 0.05 X_4 - 0.39 X_5 + 0.04 X_6$	0.63
Castor semilooper	$Y = -14.53 - 0.02 X_1 + 0.25 X_2 + 0.07 X_3 + 0.05 X_4 + 0.13 X_5 + 0.00 X_6$	0.89
Tussock caterpillar	$Y = -6.60 + 0.18 X_1 - 0.14 X_2 + 0.04 X_3 + 0.01 X_4 - 0.04 X_5 + 0.01 X_6$	0.33

X1 -Maximum temperature (°C), X2 -Minimum temperature (°C), X3 - Evening RH (%), X4 - Morning RH (%), X5 -SSH, X6 - Rainfall (mm)

Shoot and capsule borer, *Conogethes punctiferalis* infestation commenced at the beginning of capsule formation stage at 29th SMW (July) with a peak infestation of 6.21 percent bored capsules which is in contrast to findings of Duraimurugan *et al*., (2015) [6] where the infestation began from the flowering stage. Later, the infestation reduced and reached zero during at 39th SMW (maturity). Except for the maximum temperature, which has a significant negative impact on capsule borer, the results of present study corroborate with Ranganatha *et al*. (2021) [17] where they observed that min. temp., rainfall and morning/evening RH had a negative impact on capsule borer while, max. temp. influenced positively.

The multiple regression models developed could predict the occurrence of leafhoppers, capsule borer, castor spiny caterpillar and semilooper up to 49, 54, 63 and 89 percent, respectively.

Natural enemies

General predators like green lacewings, brown lacewings and ants and non-insect predators like spiders were seen feeding on insect pests of castor (Table 11). Population of spiders started to appear at 27th SMW (vegetative stage of the crop) with a population of 0.20 spiders/plant (Table 8) and maximum activity was observed during 35th SMW (maturity stage of the crop) with a population of 0.29 spiders/plant. A tachinid parasitoid, *Carcelia illota* was observed on castor spiny caterpillar (Table 11). *Brachymeria lasus* (Walker) was seen parasitizing pupa of capsule borer, *Brachymeria* sp. and *Chelonus blackburni* Cameron on lepidopteran larvae. The results are in line with the findings of Noyes (2019) [14] where, capsule borer was found to be the primary host of *Brachymeria lasus* and *Brachymeria* sp. and *Ariadne ariadne* was also parasitized by *Brachymeria lasus*.

Table 11: List of natural enemies observed on insect pests of castor during *Kharif*, 2022

Sl. No.	Common name	Scientific name	Family	Order
Predators				
1	Green lacewing	*Chrysoperla zastrowi* (Esben-Petersen)	Chrysopidae	Neuroptera
2	Brown lacewing	*Micromus* sp.	Hemerobiidae	Neuroptera
3	Ant	*Myrmicaria brunnea* (Saunders, 1842)	Formicidae	Hymenoptera
Parasitoids				
1	Chalcid wasp	*Brachymeria lasus* (Walker, 1841)	Chalcididae	Hymenoptera
2	Chalcid wasp	*Brachymeria* sp.	Chalcididae	Hymenoptera
3	Braconid wasp	*Chelonus blackburni* Cameron	Braconidae	Hymenoptera
4	Tachinid fly	*Carcelia illota* (Curran)	Tachinidae	Diptera
5	Tachinid fly	*Winthemia sumatrana* (Townsend, 1927)	Tachinidae	Diptera

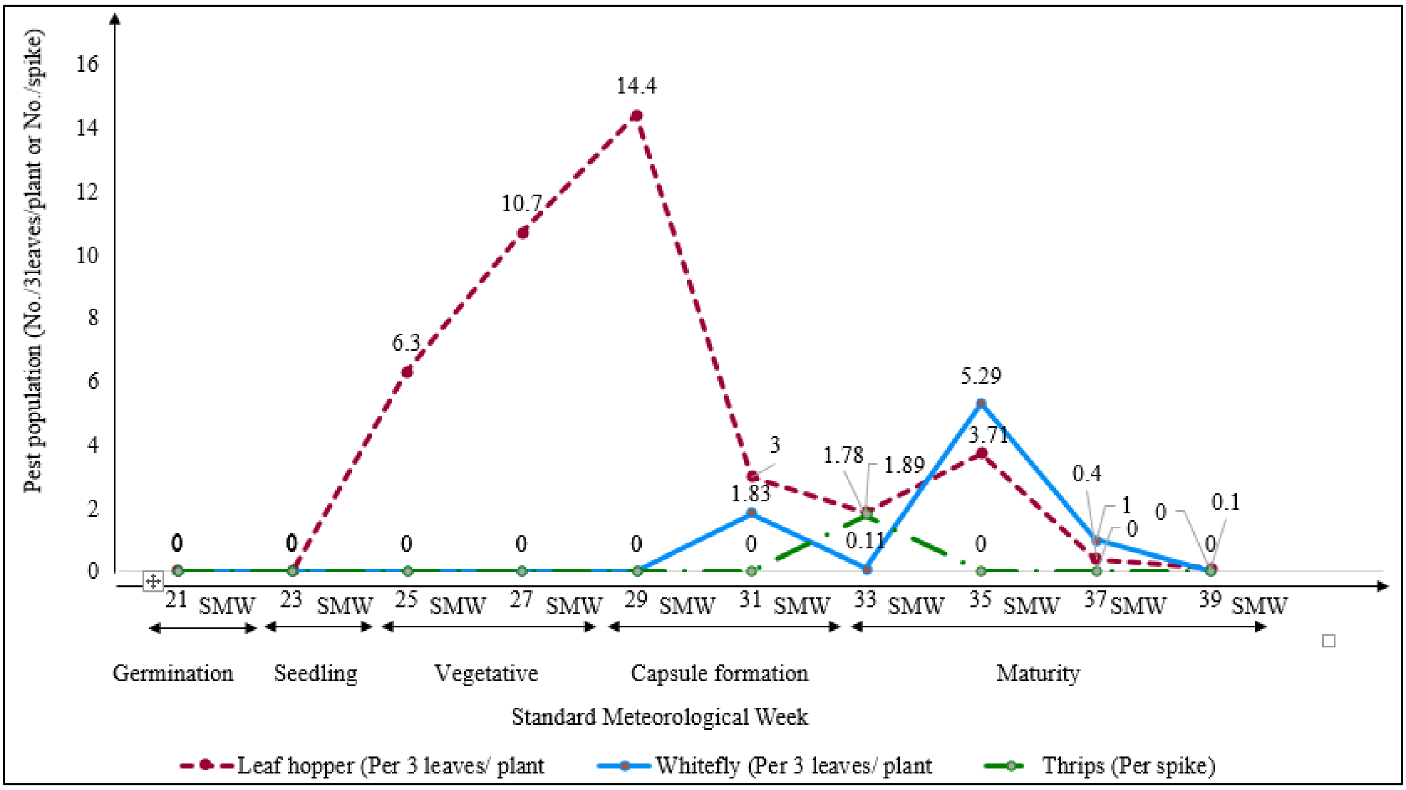

Fig 1: Population dynamics of sucking pests on castor during Kharif, 2022

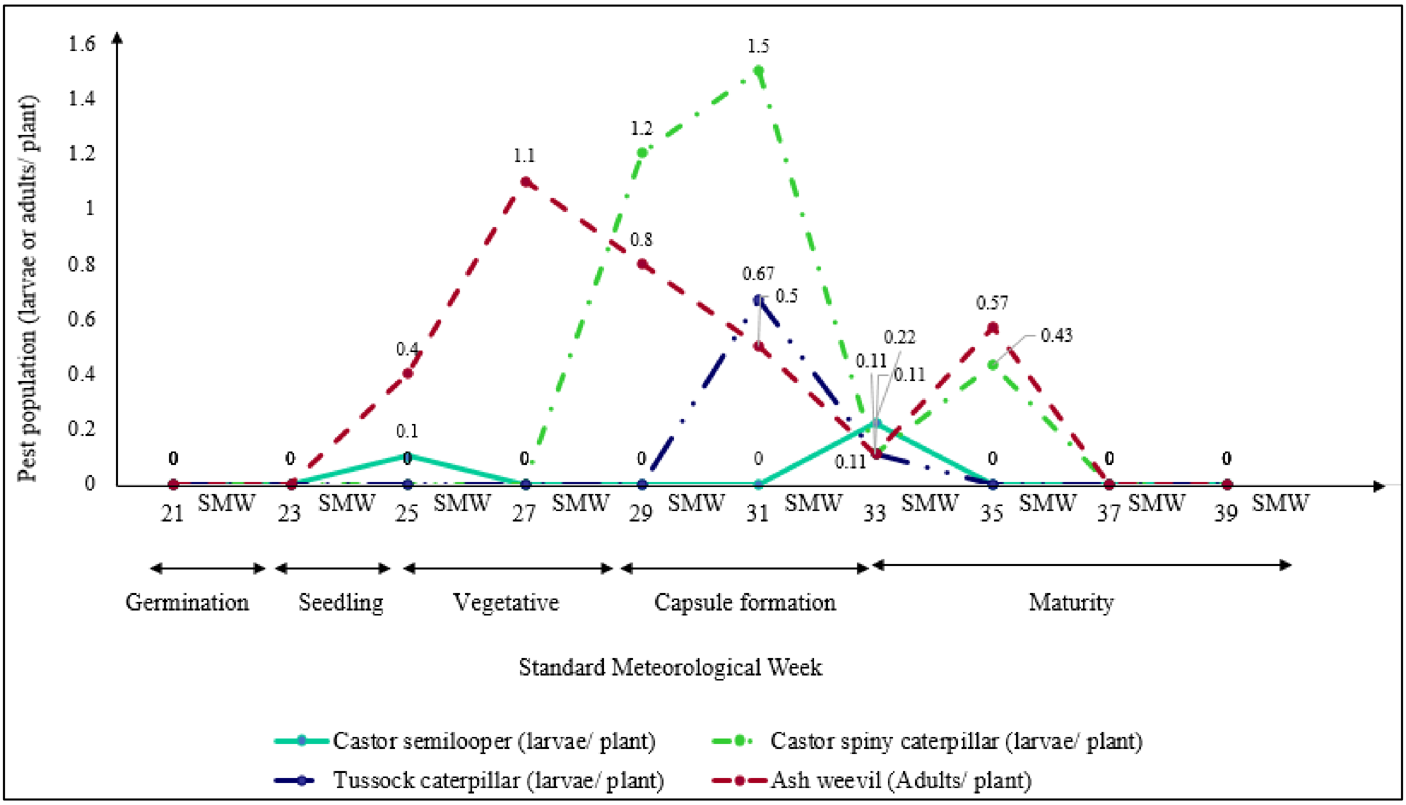

Fig 2: Population dynamics of defoliators on castor during *Kharif*, 2022

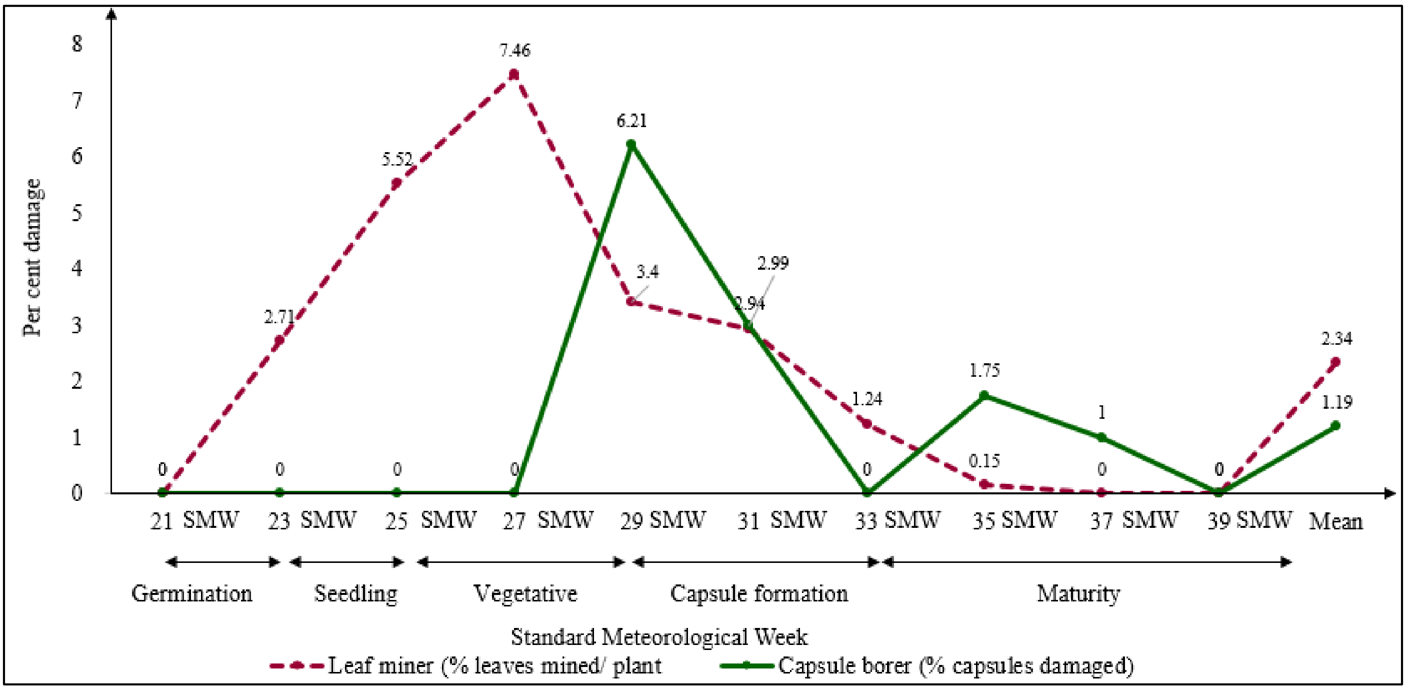

Fig 3: Population dynamics of leaf miner and shoot and capsule borer on castor during *Kharif*, 2022

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