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VB Akashe
Zonal Agricultural Research Station, MPKV, Solapur, Maharashtra, India

KC Ombase
Zonal Agricultural Research Station, MPKV, Solapur, Maharashtra, India

BN Najan
Zonal Agricultural Research Station, MPKV, Solapur, Maharashtra, India

SV Khadtare
Zonal Agricultural Research Station, MPKV, Solapur, Maharashtra, India

HN Aiwale
Zonal Agricultural Research Station, MPKV, Solapur, Maharashtra, India

Corresponding Author:
VB Akashe
Zonal Agricultural Research Station, MPKV, Solapur, Maharashtra, India

Climate change and its impact on insect-pest incidence of dry land crops in the scarcity zone of Maharashtra state

VB Akashe, KC Ombase, BN Najan, SV Khadtare and HN Aiwale

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Abstract
The recent impact of climate change influencing insect-pest incidence in important dry land crops revealed that incidence of insect-pests during last decade *viz.*, sorghum shoot fly (5-13% dead hearts), stem borer (2-10% dead hearts), delphacids (4-5 to 12-15 Nos./ shoot/plant) increased, respectively. Sunflower bud necrosis was increased from 4-5% to 9-10% whereas on safflower the occurrence of three new emerging pests *viz*., leaf eating caterpillar, stem borer and stem fly was also noticed to the extent of 15-18% infestation. Castor semi-looper and capsule borer were increased respectively @ 3-6 larvae/leaf/plant to 9-10 larvae/leaf/plant and 8-10% capsule damage to 12-15% capsule damage. The congenial climate condition required for the survival and development of sorghum shoot fly is min. 22 ^{0}C and max. 37 ^{0}C temp., RH-I 44% and RH-II 93%, stem borer min. 19 ^{0}C and max. 36 ^{0}C temp., RH-I 38% and RH-II 94%, delphacids min. 18 ^{0}C and max. 30 ^{0}C temp., RH-I 35% and RH-II 75%, safflower aphid min. 10 ^{0}C and max. 28 ^{0}C temp., RH-I 40% and RH-II 60%, safflower caterpillar min. 19 ^{0}C and max. 33 ^{0}C temp., RH-I 50% and RH-II 80%, chickpea pod borer min. 20 ^{0}C and max. 35 ^{0}C temp. with cloudy and hot weather, sunflower bihar hairy caterpillar min. 22 ^{0}C and max. 34 ^{0}C temp, pigeon pea pod borer min. 30 ^{0}C and max. 33 ^{0}C temp. and castor semi-looper min. 22 ^{0}C and max. 35 ^{0}C temp., RH-I 50% and RH-II 73%.

Keywords: Impact, insect-pest, dry land crops, scarcity zone

Introduction
The Solapur district of Maharashtra state is well known as a scarcity zone which is characterized with inadequate, erratic and ill unevenly distributed rainfall with unassured onset of monsoon. Among nine agro climatic ecological zones it is recognised as western Maharashtra scarcity (NARP) zone (MH-6) comprising of Solapur, Ahmadnagar, Dhule, part of Nasik (eastern), Sangli (eastern) etc with geographic distribution of latitude (17^o 41^l), longitude (75^o 56^l) and altitude (483.6 m). About 80 per cent agricultural area of the district is under rain fed cultivated food grains and fruit crops. Of the various reasons for low productivity, the attack of insect pests is prime important factor affectively the crop productivity even under good year condition (i. e. average rainfall and timely onset of monsoon).

The abiotic/climate factors have a dominating influence on the survival, development and reproducing capacity of insect pests and disease multiplication as well. Besides, the indiscriminate use of broad spectrum conventional insecticides results in the mortality of natural enemies, the congenial climate condition creates resurgence of key and major pests and sometimes outbreaks of the secondary/potential pests. Previously average rainfall of this region, timely onset of monsoon and normal climate under good year condition with minimum plant protection measures did not affect the crop productivity at Solapur area. So, in the present endeavour efforts have been made to study the occurrence of major insect pests irrespective of climate during *kharif* and *rabi* seasons at Solapur (MS) and advise the farmers on need based pesticide sprays. The authors have also recorded/noticed some examples of the increased intensity of key/regular pests and few of new constraints on some of the rainfed crops at Solapur region during past decade.

Material and Methods

The field experiments were conducted at Zonal Agriculture Research Station, Solapur (MS) every year during *kharif* and *rabi* of last decade with three replication in plots 5.60 x 3.60 m^2 each. The major corps of this region *viz*., pigeonpea, sunflower, pearlmillet, castor, horsegram, kidneybean, greengram and blackgram in *kharif* whereas sorghum, chickpea, sunflower and safflower in rabi season were grown under untreated uniform pest nursery trials. The trials were sown in between last week of June to last week of July every year according to the availability of sufficient moisture in the field. The observations on incidence of major insect pests were recorded at weekly intervals (on last day of the week) commencing from 5-8 days after sowing.

The data on meteorological parameters *viz*., maximum and minimum temperatures, morning and evening relative humidity, rainfall, number of rainy days, evaporation, sunshine hours etc. from June to December and Januray to April respectively for *kharif* and *rabi* season crops were collected from Auto-weather station at Zonal Agriculture Research Station, Solapur (MS). The daily weather data obtained from ZARS Meteorological observatory was converted into weekly means and only influencing parameters such as temperature, humidity, dry spell/moisture stress, cloudy weather etc. were considered responsible for the development of insect pests. The major insect pests along with intensity and congenial climate conditions required for their development are given in the Table 1 (average within a decade) and Table 2 (average for 2013-14, 2014-15, 2015-16, 2016-17 & 2017-18).

Results and Discussion

Data recorded in *kharif* season (Table 1) revealed that most of the crops at its early stage (30-35 MW) showed the incidence of leaf eating grasshoppers, the yield loss of which was recorded to the extent of 15-20%. The pigeon pea harboured the incidence of leaf folder reaching above the ETL (20-30% infestation) particularly during branching stage of the crop. The pigeon pea pod borer complex comprised the attack of pod fly, plume moth and *Heliothis* which all together destroyed the productive part of the crop at maturity and attributed to the approximate yield loss of 50-80% under untreated condition. *Kharif* Sunflower crop besides grass hopper, was found infested by sucking pests and leaf eating caterpillars during crop growth period which put into combined yield loss of 25-40%. The thrips incidence favoured by increased temperatures was responsible for the development of bud necrosis disease in sunflower (20-25%). The heavy leaf damage due to grass hoppers was recorded on pearlmillet at early stage of the crop (15-20% yield loss), particularly during dry years. Castor received the moderate incidence of sucking pests (25-35% seed yield loss) and the yield loss of 40-60% was recorded due to semi-looper. However, total defoliation of castor was occurred during outbreaks in some favourable (dry spell) years. At maturity the incidence of shoot and capsule borer was also noticed on castor the intensity of which was just at ETL i. e. 10% capsule damage. Horse gram, kidney bean, green gram and black gram possessed no major pests except moderate incidence of leaf eating grasshoppers attributed to the yield loss of 15-20% only. The surface grasshopper is a pest of warmer climate and migrating from the surrounding pastures and bunds towards the cultivated crops during early stages in particular.

During *rabi* season (Table 1) at early stages of the crop, sorghum was damaged by shoot fly (30-90% yield loss) and stem borer (about 40-50% infestation). Due to environmental fluctuation particularly in the temperature, the incidence of delphacids and aphids on sorghum caused oozing of sugar melody and excretory oily melody, respectively, which lead into contributory loss of 40-48%. Rains followed dry spell was the most congenial condition for the sporadic occurrence of army worms on sorghum (60-65% loss) during *rabi* season and also on pearl millet (10-15% loss) during *khairf* season. The longer period of cloudy weather during the season was also favours the development of lepidopterous pests like *Heliothis* species on chickpea (30-40% pod yield loss) and on safflower (8-10% capsule damage). Also, *Perigoea capensis* on safflower (15-20% leaf damage), hairy caterpillar on sunflower (25 to 38% leaf perforation) etc. The development of aphid on safflower was specifically dependent on minimum temperature. Thus, the peak incidence and survival period of aphids on safflower decided by the range of minimum temperature (10-20 ^{O}C). However, an average safflower yield loss of 40-60% only due to aphid was common during all the year under report.

The data presented in Table 2 indicated the impact of climate change on the incidence/outbreaks of insect pests since 2013-14 to 2017-18 were increased. It is observed that sorghum shoot fly (5-13% dead hearts), stem borer (2 to 10% dead hearts) and delphacids (4-5 to 12-15 Nos./shoot /plant) were on increasing trends. Sunflower bud necrosis was increased from 4-5% to 9-10% whereas on safflower besides aphid the occurrence of two new pests *viz*., leaf eating caterpillar and stem fly was also noticed to the tune of 15 to 18% infestation. Castor semi-looper and capsule borer were increased respectively @ 3-6 larvae/leaf/plant to 9-10 larvae/leaf/plant and 8-10% capsule damage to 12-15% capsule damage. However, the congenial climate conditions (temperature and relative humidity) for the development of pests are given in Table 1.

The severity of the pests and yield losses were also reported by earlier workers *viz*., sorghum shoot fly (Jotwani, 1970 and Sherwill *et. al.*, 1999) [6, 9] sunflower defoliaters (Jagdish *et al*., 2003) [5], safflower aphid with two other new emerging pests (Akashe *et al.*, 2013) [1], pigeon pea pest complex (Shanower and Romeis, 1990) [8] and castor defoliators (Singh *et al.*, 1992 and Lakshminarayana, 2010) [10, 7]. In Maharashtra, Gaikwad and Bilapate (1992) [4] recorded 36.36% reduction in castor leaves due to semi-looper, 26.35% reduction in branches per plant, 21.32% in capsules per branch and 19.58% reduction in seed yield in unprotected plots as compared to the plots protected with insecticids. Minimum temperature, relative humidity and rainfall showed positive correlation with the population of castor pests (leaf miner/semilooper) (Akashe *et al.*, 2015) [2]. The population outbreak of castor semi-looper (*A. janata* Linn.) in Ranga Reddy district of Andra Pradesh was also reported by Basappa *et al*. (2010) [3]. These findings are in the agreement with the results of present investigation.

Conclusion

From the above study it can be concluded that for increasing the production of rainfed crops under aberrant weather condition of scarcity zone of M. S., the sowing of crops at recommended sowing time, keen observations on pest occurrence irrespective of weather condition and utilization of suitable plant protection measures before taking the pest population in to severe form i. e. before reaching it at its ETL level should be followed. Also, the impact of climate change and thereby the outbreaks/severity of insect pests should be

investigated so as to advise the farmers for need based pesticide applications. Since the population growth of insect-pests predominantly dependent upon thermal time, such information is useful to be used into the Agro-Advisories for suggesting the farmers to take control action in time.

Table 1: Estimated yield losses due to Insect–Pests under Climate Change Scenario

Crop	Insect Pest	Congenial climate condition	Pest intensity/ Estimated Yield loss	Intervention/Damage
Rabi Sorghum	Shoot fly (*Atherigona soccata*)	Temp. min. 22 & max. 37 ^{0}C, RH I=44% & RH II=93%	Yield loss = 30 to 90%	Infestation occur upto a month after germination. More infestation during dry spell.
	Stem borer (*Chilo partellus*)	Temp. min. 19 & max. 36 ^{0}C, RH I=38% & RH II=94%	Yield loss = 50%	Infestation starts from 28-30 DAS onwards. Severity observed due to longer dry spell and in the untreated sorghum fields.
	Army worm (*Mythimna separata*)	Temp. min. 19 & max. 35 ^{0}C, RH I=42% & RH II=94%	Yield loss = 65%	Rains followed dry spell is the most congenial condition for its outbreak on the crops like sorghum, bajra, maize etc. Pest is nocturnal in habit and its larve cuts the leaves in a swarm. During day hourse it hibernate in the central shoot.
	Delphacids and sugary melody (*Peregrinus maidis*)	Temp. min. 18 & max. 30 ^{0}C, RH I=35% & RH II=75%	Yield loss = 40 to 48%	Delphacids colonized in the whorl during dough stage of the crop affecting the cob emergence. It is a vector of transmitting mosaic virus disease. Besides the delphacids sudden fluctuations in the temperatures also led into oozing of cell sap forming sugary melody disease.
Safflower	Safflower aphid (*Uroleucon compositae* T.)	Temp. min. 10 & max. 28 ^{0}C, RH I=40% & RH II=60%	Yield loss = 40-60%	Regular pest of safflower
	Safflower caterpillar (*Perigoea capensis*)	Temp. min. 19 & max. 33 ^{0}C, RH I=50% & RH II=80%	Infestation intensity @ 15 to 20% leaf damage (moderate level pest)	Besides key pest (aphid), it is recently developing on safflower. Safflower caterpillar infest the crop from rosittae to elongation stage of the crop.
	Stem fly (*Melanagromyza obtusa*), stem borer (*Eublema rivula*)	Temp. min. 22 & max. 37 ^{0}C, RH I=44% & RH II=93%	Minor position pest, Intensity @ 15 to 18% only in few pockets	Stem fly incidence noticed on 1 to 2 month old crop. Arrival of these two pests may be the effect of alteration in the climate factor and also the availability of alternate hosts for their perpetuation.
Chickpea	Pod borer (*Heliothis armigera*)	Temp. min. 20 & max. 35 ^{0}C, Cloudy and hot climate	Yield loss = 30 to 40%	Covered skies and hot, dry climate for longer period favors the fast multiplication of the pest.
Sunflower	Bihar hairy caterpillar (*Spilosoma obligua*)	Temp. min. 22 & max. 34 ^{0}C, Cloudy weather, dry and hot climate	25 to 38% perforated leaves	Eggs and early instar larvae develop in clusters on lower side of the leaves. Pest migrates from barren land to the field.
	White fly (*Bemisia tabaci*), Jassids (*Empoasca devastans*) and Thrips (*Thrips palmi*)	Temp. min. 30 & max. 38 ^{0}C, Either heavy or scanty rains and moisture stress	Yield loss = 30 to 40%, Bud Necrosis= 20-25%	Increased temperatures favor the attack of these sucking pests. Thrips are responsible for the development of bud necrosis disease in sunflower.
Pigeon pea	Pod borer (*Helicoverpa armigera*), plume moth (*Exelastis atmosa*) and pod fly (*Melanagromyza obtusa*)	Temp. min. 30 & max. 33 ^{0}C, Dry and hot climate with intermittent cloudy weather and dry spell after rainy season.	Yield loss = 50 to 80%	Pod borer complex destroying the productive part of the crop at maturity stage and thus gaining importance irrespective of climate change.
	Leaf folder (*Anticarsia irrorata*)	Temp. min. 30 & max. 35 ^{0}C, RH I=35-40% & RH II >60%	Yield loss = 20 to 30%	Pest occur at branching stage of the crop and continued up to flowering. Under congenial climate the spreading and bunchy pod forming type varieties often susceptible
Castor	Semilooper (*Achoea janata*)	Temp. min. 22 ^{0}C & max. 35 ^{0}C, RH I 70% & RH II 73%	Yield loss = 40 to 60%	Pest often serious during July to September. Full grown larvae are voracious feeder. Total defoliation occurs duing outbreaks.
	Jassids (*Empoasca devastons*) and white fly (*Bemisia tabaci*)	Temp. min. 30 ^{0}C & max. 40 ^{0}C, Dry spell, Scanty rains	Yield loss = 25 to 35%	Increased temperatures and also the polyphogous nature of the pest creates severity.
	Shoot & Capsule borer (*Conogethes punctiferalis*)	Temp. min. 24 ^{0}C & max. 38 ^{0}C, RH I 40% & RH II 70%	10-12% Capsule damage	Magnitude of infestation of this pest is high when castor cultivation is mainly rainfed.
Sunflower, safflower, castor, horsegram, mothbean, pearlmillet	Surface grass hopper (*Chrotogonus trachypterus*)	Temp. 25 to 38 ^{0}C, Dry spell, moisture stress	Yield loss = 15 to 20%	It is a pest of warmer climate and migrating from surrounding pastures towards the cultivated crops. Its abundance favoured during dry years. Localized outhbreaks often occur at initial stage of the crops.

Table 2: Climate Change-Severity of insect–pest under dry land condition (Solapur region)

Crop	Insect Pest	Intensity of the pest/occurrence				
		2013-14	2014-15	2015-16	2016-17	2017-18
Rabi Sorghum	Shoot fly	5 to 8% dead hearts	8 to 9% dead hearts	10 to 12% dead hearts	10 to 12% dead hearts	10 to 13% dead hearts
	Stem borer	2 to 3% dead hearts	0 to 3% leaf damage and 2 to 3% dead hearts	0 to 3% leaf damage and 8 to 10% dead hearts	0 to 3% leaf damage and 8 to 10% dead hearts	2 to 3% leaf damage and 8 to 10% dead hearts
	Delphacids	4 to 5 No./Shoot/Plant	5 to 10 No./Shoot/Plant	10 to 12 No./Shoot/Plant	10 to 12 No./Shoot/Plant	12 to 15 No./Shoot/Plant
	Army worm	1 to 2 cuts/leaf/plant	3 to 4 cuts/leaf/plant	3 to 5 cuts/leaf/plant	3 to 5 cuts/leaf/plant	5 to 6 cuts/leaf & 8-10% inf.
Sunflower	Hairy Caterpillar	6 to 8 infested leaves / plant	2 to 3 infested leaves / plant	0 to 2 infested leaves/plant	0 to 2 infested leaves/plant	2 to 3 infested leaves at border
	Thrips, Jassids, White flies	3 to 5 No. each/plant and 4 to 5% necrosis disease	5 to 10 No. each plant and 8 to 10% necrosis disease	5 to 10 No. each plant and 6 to 8% necrosis disease	5 to 10 No. each plant and 9 to 10% necrosis disease	5 to 10 No. each plant and 6 to 8% bud necrosis disease
Safflower	Leaf eating caterpillar	Traces	5 to 10% leaf damage	6 to 10% leaf damage	6 to 10% leaf damage	8 to 10% leaf damage
	Stemborer/Stem fly	Traces	0 to 2% plant infestation	3 to 5% plant infestation	15 to 18% plant infestation	3 to 6% plant infestation
	Aphid	100-220 Nos./5 cm twig/plant	120-300 Nos./5 cm twig/plant	90-250 Nos./5 cm twig/plant	80-150 Nos./5 cm twig/plant	100-180 Nos./5 cm twig/plant
	Pod borer	0-3% infestation	2-4% infestation	3-5% infestation	4-5% leaf & 2-4% pod damage	4-5% leaf & 3-5% pod damage
Pigeon pea	Pod borers	5 to 10% leaf and 15 to 20% pod infestation	5 to 10% leaf and 25 to 40% pod infestation	5 to 10% leaf and 25 to 30% pod infestation	5 to 10% leaf and 25 to 30% pod infestation	8 to 10% leaf and 15 to 16% pod infestation
	Leaf folder	2 to 3 folds/plant	2 to 5 folds/plant	3 to 5 folds/plant	3 to 5 folds/plant	3 to 4 folds/plant
Chickpea	Gram pod borer	6 to 8% pod damage	5 to 8% leaf and pod damage	5 to 6% leaf and 10-15% pod damage	5 to 6% leaf and 10-15% pod damage	3 to 5% leaf and 8-10% pod damage
Castor	Semi-looper	3 to 6 larvae/leaf/plant	3 to 5 larvae/leaf/plant	8 to 10 larvae/leaf/plant	9 to 10 larvae/leaf/plant	2 to 4 larvae/leaf/plant
	Leaf miner	2 to 5 mines /leaf/plant	2 to 4 mines /leaf/plant	2 to 3 mines/leaf/plant	2 to 3 mines/leaf/plant	5 to 6 mines/leaf/plant
	Capsule borer	8 to 10% capsule damage	10 to 15% capsule damage	10 to 12% capsule damage	12 to 15% capsule damage	8 to 10% capsule damage
	Jassids/ white flies	2 to 3 No. each/leaf/plant	2 to 5 No. each/leaf/plant	4 to 6 No. each/leaf/plant	4 to 6 No. each/leaf/plant	3 to 5 No. each/leaf/plant
Sunflower Safflower Horsegram Mothbean Greengram, Blackgram Pearlmillet Sorghum	Grasshopper	2 to 5% leaf damage	5 to 6% leaf damage	15 to 18% leaf damage	15 to 18% leaf damage	8 to 10% leaf damage

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