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Seasonal incidence of major insect pest's complex of sorghum, [*Sorghum bicolor* L. (Moench)]

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Abstract
The present study was conducted at the entomological research field, College of Agriculture, RVSKVV, Gwalior, Madhya Pradesh during the *Kharif* season of 2019-2020. The sorghum crop was sown with CSV-13 variety by following recommended agronomic practices and fertilizer application with 45 cm row to row and 15 cm plant to plant spacing. The results revealed that *A. biguttula biguttula* was first observed when the crop age was about 18 days old as in 30th SMW while its peak incidence was seen during 12WAS *i.e.*, 38th SMW with 41 jassids (nymph/adult per leaf) per plant, however, this shows significant positive correlation (r = 0.642, 0.643 and 0.701, respectively) with morning and evening relative humidity and rainfall. Further, *R. maidis* was first recorded during the 31st SMW when the crop age was 26 days old and showed peak incidence during 37th SMW with 54 aphids per leaf. This was found to be significantly positively correlated (r = 0.630, 0.562 and 0.601, respectively) with morning and evening relative humidity and rainfall, respectively. *A. soccata* was first observed on the crop at7 DAS *i.e.*, 28th SMW with its peak infestation during 29th SMW with 11.67% dead hearts which showed that maximum temperature and evaporation showed a positive significant correlation (r= 0.771 and 0.595, respectively) and morning relative humidity showed a negative significant correlation (r= -0.612). Finally, *C. partellus* was first observed at 34 DAS *i.e.*, 33rd SMW with its peak during 37th SMW with 23.7% dead hearts (plant infestation). This was found to exhibit a positive significant effect (r = 0.631, 0.544 and 0.645) with morning and evening relative humidity and rainfall, respectively.

Keywords: *Amrasca biguttula biguttula* (Ishida), *Atherigona soccata rondani*, *Chilo partellus* (Swinhoe.), *Rophalosiphum maidis* (Koch), sorghum, succession, weather parameters

1. Introduction
Sorghum [*Sorghum bicolor* L. (Moench)] is a strong and healthy plant that belongs to the grass family while it looks similar to maize and sugarcane plants. It is an important food crop for a large section of people in Africa and Asia and also the main source of fodder and industrial raw material. It ranks third in area and production after rice and wheat. Some researchers believe that global warming will make sorghum a more valuable product in the forthcoming years because of its less need for water (millermagazine.com). Sorghum grain is an important raw material for the starch industry and is also used as cattle and poultry feed. This crop also has export potential. Sorghum is also used in the production of starch, biscuits, sugar, and alcohol. Sorghum grain is a principal source of alcoholic beverages in many countries. The major sorghum growing areas include the Great Plains of North America, sub-Saharan Africa, North-Eastern China, India, Argentina, Nigeria, Egypt and Mexico, France and Spain are major producers of sorghum in Europe (Anonymous, 2017) [2]. India contributes about 16% of world sorghum production and 4th largest producer in the world. The USA is also the largest producer in the world with a production of 9.27 MMT followed by Nigeria (6.80 MMT) and Mexico (4.70mmt) (Vilas *et al*. 2011) [28]. The annual global production of sorghum is 59.53 million metric tons under 40.03 mha with a productivity of 1.49 t/ha. In India, the annual production for the year 2018 was 3.75mmt under 4mha with a productivity of 1.83t/ha (Santosh, 2019) [22]. Maharashtra is the leading producer in the country (1.81mmt), followed by Karnataka (1.13mmt) and Madhya Pradesh (0.57 MMT). These three states as a whole represent 60% of the country's sorghum production (APEDA, 2018) [4]. In Madhya Pradesh, sorghum is majorly grown as a Kharif crop, with an annual production of 0.57mmt cultivated under an area of 2.05mha with a productivity of 1.95t/ha (Anonymous, 2019) [3].
Despite all the adaptable benefits of the crop, its average productivity is still low because the grain yield is influenced by various biotic and abiotic factors. More than 150 species of insects have been reported attacking sorghum crops during different stages of their growth (Jotwani *et*

al., 1980) [10]. Among them shoot fly, *Atherigona soccata* Rondani (Diptera: Muscidae) is one of the most important insect pests of sorghum in India. The pest attacks the crop only in the early stage of the crop growth and lasts up to four weeks (Daware *et al*., 2013). The other most damaging species are *Chilo partellus*, *Busseola Fusca* and *Eldana saccharina* (Songa *et al*., 2001). High damage is seen in maize stalk and nearly 80% yield loss is seen in sorghum by *Chilo partellus* was reported in the young crop, whereas, similar infestations induced no significant loss when plants were infested soon (6 days) after emergence (Van den berg, 2009) [26]. Keeping in view, the present studies were carried out on the seasonal incidence of major insect pest complex of sorghum.

2. Material and Methods

The present study was conducted at the entomological research field, College of Agriculture, RVSKVV, Gwalior, Madhya Pradesh during the *Kharif* season of 2019-2020. Gwalior is situated in the northern part of Madhya Pradesh and lies at 26º14'N and 78º16'E at 211.52 masl. The region has a sub-tropical climate receiving 820.4mm average annual rainfall. The sorghum crop was sown with CSV-13 variety by following recommended agronomic practices and fertilizer application with 45 cm row to row and 15 cm plant to plant spacing. Observations were recorded on the incidence of all the insect pests on randomly selected 10 plants at weekly intervals. The number of nymphs and adults of jassid and aphid were recorded per plant. For the insects like shoot fly and stem borer, the number of dead hearts was taken as a parameter for estimating the population at the early stage of the plant, while in the case of the later stage the per cent infestation of the plant was taken to estimate its population. The meteorological data of the corresponding weeks was also recorded. The insect population was correlated with the meteorological data using a suitable method of analysis.

3. Result and Discussion

3.1 Succession of insect complex of sorghum

For the succession of insect complex of sorghum, ten randomly selected plants were observed for incidence. For recording shoot fly and stem borer, the per cent dead heart infestation is taken into count. Studies on insect pest succession and field incidence revealed that about four species of insect pests (Aphid, leafhopper, shoot fly and stem borer) were observed to be associated with various stages of the sorghum crop as depicted in Table 1. The first major group of insects to attack in the vegetative stage were jassid, and aphid all these were available. Shoot fly was available from seedling to vegetative stage of the crop, whereas stem borer was available from the vegetative stage to maturity of the crop.

Table 1: The succession of insects on sorghum at Gwalior during *Kharif* season 2019

Common name	Scientific name	Order	Family
Aphid	*Rophalosiphum maidis* (Koch)	Hemiptera	Aphididae
Jassid	*Amrasca biguttula biguttula* (Ishida)	Hemiptera	Cicadellidae
Shoot fly	*Atherigona soccata* (Rodnani)	Diptera	Muscidae
Stem borer	*Chilo partellus* (Swinhoe.)	Lepidoptera	Pyralidae

3.2 Seasonal incidence of insect complex of sorghum

3.2.1 Jassid, *Amrasca biguttula biguttula* (Ishida) (Hemiptera: Cicadellidae)

In the present study, the results reveal that there was no sucking pest incidence up to 3 weeks after sowing. The *A. biguttula biguttula* was first observed when the crop age was about 18 days old as in 30th SMW (Table 2) and thereafter observations were recorded regularly twice/ SMW. The pest was present on the crop during most of the crop stages except the initial seedling vegetative stage and remained active up to the crop maturity of the crop as it prevailed actively between 29th SMW to 44th SMW. Whereas, a higher population was observed 36th to 39th SMW. While its peak incidence was seen during 12 weeks after sowing *i.e.*, 38th SMW with 41 jassids (nymph + adult/leaf) per plant. After 44th SW the jassid population was completely absent.

Correlation studies depicted in Table 3 revealed that morning and evening relative humidity and rainfall showed a significant positive correlation (r = 0.642, 0.643 and 0.701, respectively) with the *A. biguttula biguttula* population. Further, minimum temperature showed a positive correlation (r = 0.280) while the maximum temperature and evaporation showed, a negative correlation (r = -0.340 and -0.451, respectively) with the *A. biguttula biguttula* population but statistically found to be non-significant.

3.2.2 Aphid, *Rophalosiphum maidis* Koch (Hemiptera: Aphididae)

The number of *R. maidis* (nymph + adult) was recorded at weekly intervals and the average data per leaf is presented. *R. maidis* was first recorded during the 31st SMW with 0.2 aphid nymph + adult/leaf (Table 2). Thereafter, the *R. maidis* population started increasing gradually from 31st SMW with a higher peak, (54 aphid nymph + adult/leaf) during 37th SMW with 54 aphids per leaf. After 37th SMW, there was a sharp decline in the *R. maidis* population and it was available up to 45th SMW which was near up to harvesting time.

Correlation studies depicted in Table 3 revealed that morning and evening relative humidity and rainfall showed a significant positive correlation (r = 0.630, 0.562 and 0.601, respectively) with the *R. maidis* population. Further, minimum temperature showed a positive correlation (r = 0.221) while the maximum temperature and evaporation showed, a negative correlation (r = -0.284 and -0.406, respectively) with the *R. maidis* population, but statistically found to be non-significant.

The present findings of both *A. biguttula biguttula* and *R. maidis* incidence conform to the findings of Mote and Jadhav (1993), Waghmare *et al*., (1993), Mustafa *et al*., (1996a) and Kore A T (2011) [17, 29, 18, 14]. However, the present findings contradict the findings of Borade *et al*., (1993) and Tiwari (2004) [6, 25].

3.2.3 Shoot fly, *Atherigona soccata* (Rodnani) (Diptera: Muscidae)

The observations were taken twice per standard meteorological week and observations were based on the per cent dead hearts present (Table 2). Incidence of *A. soccata* was first observed on the crop at 7 DAS *i.e.*, 28th SMW with 2.34% dead heart when the crop was in the seedling stage.

The pest prevailed from 28th SMW and reached its peak population with 11.67% dead hearts *i.e.*, during 29th SMW. The pest was present on the crop till the vegetative stage of the crop *i.e.*, 31st SMW after which it was completely absent.
Correlation studies revealed that maximum temperature and evaporation showed a positive significant correlation (r= 0.771 and 0.595, respectively) and morning relative humidity showed a negative significant correlation (r= -0.612) with the *A. soccata* population. Further, minimum temperature showed a positive correlation (r = 0.402) and evening relative humidity and rainfall showed a negative correlation (r= -0.129 and -0.181, respectively) with the *A. soccata* population but statistically were found to be non-significant.

3.2.4 Stem Borer, *Chilo partellus* (Swinhoe) (Lepidoptera: Pyralidae)
In the present study, the observations of *C. partellus* incidence were taken in the same manner as in that of shoot fly by considering the per cent dead heart infestation. The observations were recorded twice per standard meteorological week for a better understanding of the pest incidence. The data in Table 2 revealed that the incidence of *C. partellus* was first observed when the dead heart was recorded at 34 DAS *i.e.*, 33rd SMW with 3.7% dead hearts. Even when the pest population appears on a 30-day old plant, the symptoms *i.e.*, dead hearts appear a week after the pest appearance on the plants. Thereafter, the incidence of *C. partellus* started increasing from 34th SMW up to 37th SMW with its peak (23.7% dead hearts plant infestation). After which the pest population showed a decline from 38th SMW but the pest infestation persisted till harvest maturity *i.e.*, 46th SMW of the crop in minimal levels but there was no complete absence.
Correlation studies depicted in Table 3 revealed that morning and evening relative humidity and rainfall showed a significant positive correlation (r = 0.631, 0.544 and 0.645, respectively) with *C. partellus* population. Further, minimum temperature showed a positive correlation (r = 0.280) while the maximum temperature and evaporation showed, a negative correlation (r = -0.340 and -0.451, respectively) with *C. partellus* infestation per plant but statistically found to be non-significant.
The present finds of *A. soccata* and *C. partellus* incidence were comparable with the findings of Anonymous (2000), Jalali and Singh (2002), Raigar *et al*., (2002a), Kumar and Alam (2017) and Singh *et al*. (2018) [1, 9, 20, 16, 23]. However, the present finding contradicts the finding of Baikal (2000), Kandalkar *et al*., (2002), Venkatesh and Baikal (2002), Raigar *et al*., (2002b), Karibasavaraj and Baikal (2006), Divya *et al*., (2009a), Sable *et al*., (2009), Kore *et al*., (2013), Pavan Kumar *et al*., (2015) and Keerthi *et al*., (2017) [5, 11, 27, 20, 12, 8, 21, 15, 19, 13].

Table 2: Incidence of insect pest complex on sorghum at Gwalior during *Kharif* 2019.

SMW	Mean population (nymph + adult) per leaf		*A. soccata* (% dead heart)	*C. partellus* (% dead heart/ plant infestation)	Temperature		Relative Humidity		Rainfall (mm)	Evaporation (mm)
	A. biguttula biguttula	*R. maidis*			Maximum (ºC)	Minimum (ºC)	Morning Humidity (%)	Evening Humidity (%)		
28	0.00	0.00	2.34	0.00	34.50	26.40	79.40	59.30	48.20	5.50
29	0.00	0.00	11.67	0.00	37.70	26.40	75.40	45.00	2.40	7.60
30	1.30	0.00	7.40	0.00	35.10	25.70	85.10	66.00	38.60	3.30
31	3.80	0.20	1.70	0.00	33.20	25.90	91.30	64.30	9.20	4.80
32	5.60	3.00	0.00	0.00	32.90	24.90	83.10	66.10	22.40	3.80
33	7.00	8.00	0.00	3.70	31.10	24.10	91.10	84.0	59.80	2.80
34	11.00	12.00	0.00	9.00	32.30	24.40	89.90	72.10	117.80	3.60
35	18.00	27.00	0.00	12.70	33.50	25.20	90.10	67.70	21.80	3.50
36	27.00	35.00	0.00	17.33	33.40	25.10	90.90	67.60	67.40	3.60
37	39.00	54.00	0.00	23.70	32.80	24.80	94.90	78.30	70.00	2.97
38	41.00	42.00	0.00	19.60	30.20	23.00	94.10	77.10	123.80	3.10
39	35.00	36.00	0.00	14.33	29.00	22.20	95.70	80.00	89.80	1.08
40	21.00	29.00	0.00	10.45	31.64	21.50	90.80	66.00	31.40	3.40
41	12.00	17.00	0.00	8.00	33.20	17.98	80.20	40.40	0.00	5.20
42	6.00	11.00	0.00	5.87	32.60	17.50	90.50	44.40	0.00	5.00
43	2.00	6.00	0.00	3.24	31.44	14.10	89.40	31.70	0.00	4.00
44	0.43	3.00	0.00	1.25	32.00	16.40	89.00	42.28	0.00	4.00
45	0.00	0.76	0.00	0.87	30.80	14.00	88.90	37.30	0.00	2.50
46	0.00	0.00	0.00	0.45	29.70	14.70	84.40	43.10	0.00	2.60

Table 3: Correlation (r) and regression coefficient (b_{yx}) of abiotic factors on pest complex on sorghum crop during *Kharif* 2019

Insects		Weather factors					
		Temperature		Relative Humidity		Rainfall (mm)	Evaporation (mm)
		Max.	Min.	Mor.	Eve.		
A. biguttula biguttula (nymph+ adult/leaf)	r	-0.340NS	0.280NS	0.642**	0.643**	0.701**	-0.451NS
	byx	-	-	1.65	0.555	0.24	-
R. maidis (nymph+ adult/leaf)	r	-0.284NS	0.221NS	0.630**	0.562*	0.601**	-0.406NS
	byx	-	-	1.96	0.59	0.25	-
A. soccata (% dead hearts)	r	0.771**	0.402NS	-0.612**	-0.129NS	-0.181NS	0.595**
	byx	1.18	-	-0.35	-	-	1.32
C. partellus (% dead hearts)	r	-0.267NS	0.215NS	0.631**	0.544*	0.645**	-0.383NS
	byx	-	-	0.88	0.25	0.12	-

*Significant at p=0.05, **Significant at p=0.01, NS= Non-Significant

4. Conclusion

The *A. biguttula biguttula* was first observed when the crop age was about 18 days old as in 30th SMW. While its peak incidence was seen during 12WAS *i.e.*, 38th SMW which showed a significant positive correlation with morning and evening relative humidity and rainfall. *R. maidis* was first recorded during the 31st SMW *i.e.*, 26 DAS and the peak incidence was seen during 37th SMW which showed a significant positive correlation with morning and evening relative humidity and rainfall. Further, *A. soccata* was first observed on the crop at 7 DAS *i.e.*, 28th SMW with its peak infestation during 29th SMW. This revealed that maximum temperature and evaporation showed a significant positive correlation and morning relative humidity showed a significant negative correlation with the incidence of shoot fly during the season. Stem borer was first observed at 34 DAS *i.e.*, 33rd SMW. The highest *C. partellus* infestation was identified during 37th SMW. This revealed that morning and evening relative humidity and rainfall showed a significant positive correlation with stem borer infestation.

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