Range Management and Agroforestry 44 (2) : 298-306, 2023
ISSN 0971-2070 (Print); 2249-5231 (Online)
https://doi.org/10.59515/rma.2023.v44.i2.11

Research article

Effect of date of sowing and weather factors on infestation of *Atherigona soccata* (Rondani) and yield parameters of forage sorghum

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Received: 9th August, 2022 Accepted: 11th July, 2023

Abstract

Ecofriendly strategies for the management of sorghum shoot fly, *Atherigona soccata* helps in addressing the issues related to insecticides load on forage crop. The present study was carried out to know the suitable date of sowing on damage indices of sorghum shoot fly and green fodder yield in sorghum. The staggered sowing technique at a different time intervals was used, starting from 2nd fortnight of March (12th SMW) to 1st fortnight of July (27th SMW). Oviposition in terms of eggs per 10 plants and dead heart percentage was recorded to be low in 18th SMW (1st fortnight of May) sown crop (eggs: 6.66 and dead heart: 25.46%), but it was found to be highest in 1st fortnight of July (27th SMW) sown crop (eggs: 21.95 and dead heart: 65.45%). The correlation of shoot fly infestation in relation to weather parameters revealed that egg load and dead hearts were negatively correlated with maximum temperature and positively correlated with minimum temperature, relative humidity and rain fall. Green fodder yield was recorded to be highest and lowest for the crop sown on 18th SMW (409 q/ha) and 27th SMW (302 q/ha), respectively. The study indicated that 1st fortnight of May was the best time to escape from the sorghum shoot fly attack.

Keywords: *Atherigona soccata,* Correlation, Dead heart, Green fodder yield, Oviposition, Sorghum

Introduction

Sorghum (*Sorghum bicolor*) is one of the most important food and fodder crop grown throughout the world. Sorghum is mainly cultivated for forage purpose in Punjab as livestock is one of the important components of financial system of Punjab contributing 14% to the state domestic product and 1/3rd to the gross price of agricultural output. The daily fodder availability in Punjab is about 10-12 kg per animal and that is quite low in assessment to the maximum reliable necessities of 40-50 kg per animal (Grover *et al.,* 2011). Sorghum is grown in two seasons *i.e. kharif* (June-July to September-October) and rabi (September-October to February-March). *Kharif* sorghum yields higher than *rabi* sorghum as in *rabi* season moisture availability is less and the prevalence of pests and diseases is higher. Due to its drought tolerant nature, it serves as a critical element in dry land agriculture. However, higher yield in sorghum is not realized in distinctive agro climatic regions due to the impact of various biotic and abiotic factors. The shoot fly is considered as a serious pest in India during the seedling stage. Female shoot fly lays boat shaped eggs on lower side of leaf blades during the initial weeks of crop growth. Larvae attack the primary shoot during the seedling stage and causes dead heart. Host plant resistance (HPR) is a heritable plant attribute, important part of the integrated pest management (IPM) and can be used to reduce the damage of different insect pests of sorghum by using resistant genotypes (Keerthi *et al.*, 2021). Different nutrients like carbohydrates and HCN contributed towards the resistance mechanism in sorghum against shoot fly infestation (Kumari *et al.*, 2021). Borad and Mittal (1983) reported nearly 32% yield losses in sorghum due to attack of insect pests, of which 5% yield loss was due to the attack of shoot fly, *A. soccata* (Jotwani, 1983). Due to shoot fly damage, a loss of 80-90% of grain, and 68% of fodder yield was recorded in India (Balikai and Bhagwat, 2009; Kahate *et al.*, 2014; Prasad *et al.*, 2015). Abiotic factors like seasonal temperature and moisture governs the attack of sorghum shoot fly to a great extent. Hence, agronomic manipulations *via* altering the time of sowing could be helpful to identify the suitable period of sowing for escaping severe attack of *A. soccata* during the seedling stage. In order to rationalize the use of insecticides on forage sorghum and considering the importance of pest in sorghum crop, the present investigation was undertaken to develop a holistic and sound management practice of sorghum under Punjab conditions.

Materials and Methods

Experimental site and treatments: To ascertain the influence of date of sowing and weather factors on damage indices and green fodder yield, the field experiments were conducted at Forage Research Farm, Punjab Agricultural University, Ludhiana. Sorghum hybrid PSC 4 was sown in a plot size of 3 x 4 m^2 with row to row and plant to plant spacing of 30 cm and 15 cm, respectively on 8 different dates of sowing (DOS) *i.e*. 2nd fortnight of March (T1: 12th SMW, DOS - 20th March), 1st fortnight of April (T2: 14th SMW, DOS-3rd April), 2nd fortnight of April (T3: 16th SMW, DOS-17th April), 1st fortnight of May (T4: 18th SMW, DOS-1st May), 2nd fortnight of May (T5: 20th SMW, DOS-16th May), 1st fortnight of June (T6: 23rd SMW, DOS-5th June), 2nd fortnight of June (T7: 25th SMW, DOS-19th June), 1st fortnight of July (T8: 27th SMW, DOS-3rd July) in *kharif* season of 2018 and 2019. The above treatments were laid in randomized block design with three replications. The crops were raised as per recommended package of practice for fodder sorghum cultivation.

Meteorological conditions: Weekly meteorological data (13 to 31 SMW) on maximum and minimum temperature, maximum and minimum relative humidity and rain fall were obtained from Agro Meteorological Observatory situated in Research Farm of Punjab Agricultural University, Ludhiana. The climatic factors were correlated with oviposition and dead heart percentage after germination of the crop. The maximum temperature during the observation period was recorded to be the lowest in 13 to 16 SMW (34.1˚C; 2018 and 32.9˚C; 2019) for 2nd fortnight of March (12th SMW) sown crop. Similar trend also observed for minimum temperature. However, the highest maximum temperature was recorded from 19 to 22 SMW (39.9 ˚C; 2018) and 21 to 24 SMW (41.1 ˚C; 2019). Similarly, the peak minimum temperature was observed during 28 to 31 SMW (27 ˚C) and 26 to 29 SMW (27.2 ˚C) in 2018 and 2019, respectively. Maximum relative humidity during the observation period (13 to 31 SMW) ranged from 46-82% in which 13 to 16 SMW recorded 68.5% and then gradually decreased to the lowest (46%) during 19 to 22 SMW and then gradually increased to the highest (82%) during 28 to 31 SMW in 2018. Similar trend was also recorded in 2019. The data on minimum relative humidity also revealed the same pattern in two years of study. Total rainfall during the period of observation indicated low rainfall during 19 to 22 SMW (3.6 mm; 2018) and 21 to 24 SMW (11.3 mm; 2019). The data depicted that from 28 to 31 SMW received the highest amount of rainfall of 324 mm (2018) and 312 mm (2019) (Table 1).

Observations: Shoot fly laid boat shaped eggs on the lower side of the leaf. During the seedling stage the plants infested by *A. soccata* resulted in wilting and drying of the central shoot referred to as a dead heart. The observations on oviposition in terms of number of eggs and percentage dead heart were recorded at 7, 14, 21 and 28 days after germination

Table 1. Weekly weather parameters during observation period

Sowing week (SMW)	Period of obse-rvation (SMW)	Max.Temp. (°C) 2018	Max.Temp. (°C) 2019	Min.Temp. (°C) 2018	Min.Temp. (°C) 2019	Max. R (%) 2018	Max. R (%) 2019	Min. RH (%) 2018	Min. RH (%) 2019	Rainfall (mm) 2018	Rainfall (mm) 2019
12th	13-16	34.1	32.9	18.5	17.7	68.5	79.5	29.5	34.7	10	37.8
14th	15-18	36.1	35.8	20.8	20.3	58	61.7	25.75	25.5	25.4	46.1
16th	17-20	38.2	37.7	23	21.8	51.7	53.2	23.2	21.2	19	23.4
18th	19-22	39.9	38.6	24.5	23.1	46	53.5	19.7	24	3.6	16.9
20th	21-24	39.8	41.1	25.4	25.2	51.2	48.5	27.5	23	104.6	11.3
23rd	24-27	36.1	38.8	25.6	27.0	68.5	61	46.2	34.2	156.8	42.3
25th	26-29	34.3	35.5	26.7	27.2	78.7	73.5	61.7	56	321.8	180
27th	28-31	34.5	33	27.0	26.7	82	83.5	64.5	71.5	324.2	312.8

SMW: Standard meteorological week

(DAG) on 10 and 100 randomly selected plants, respectively in each plot. Growth parameters like plant height (m), stem girth (mm) and yield (q/ha) data were recorded. Mean plant height and stem girth was recorded at the crop stage near harvesting by taking five randomly selected plants from each plot. Green fodder yield (q/ha) data was recorded at 50% flowering stage.

Statistical analysis: The treatments comprised eight plots and each plot had 3 replications. Treatment means separated by LSD (P<0.05). Square root and arc sine transformed values were used for analyzing the oviposition per 10 plants and dead heart percentage, respectively. The coefficient of correlation for mean oviposition and dead heart percentage was correlated with the weather variables namely- maximum temperature, minimum temperature, maximum relative humidity, minimum relative humidity and rainfall for different dates of sowing in kharif 2018 and 2019. Simple regression analysis was carried out to know the most important weather factors with respect to shoot fly infestation during the seedling stage. The coefficient of determination (R^2) was used in order to know the strong environmental factors that influence oviposition and dead heart by *A. soccata*. The correlation coefficient was figured out by performing correlation analysis using CPCS software.

Results and Discussion

Oviposition: The data regarding oviposition per 10 plants were recorded at a weekly interval from 7 DAG to 28 DAG and the mean egg count was calculated in each treatment. The observation revealed significant differences among the different dates of sowing. The mean oviposition per 10 plants recorded indicated the lowest (5.00) in 18th SMW (1st fortnight of May and highest (21.50) in 27th SMW (1st fortnight of July) (Table 2). However, in the year 2019 mean number of eggs per 10 plants were recorded to be lowest (8.16) in 20th SMW (2nd fortnight of May) and highest (22.41) in 27th SMW (1st fortnight of July) (Table 3). The pooled mean oviposition data of two years 2018-19 depicted

Table 2. Oviposition and dead hearts due to *A. soccata* as influenced by different sowing dates during 2018

Treatment	Oviposition per 10 plants	Dead heart (%)				
		7 DAG	14 DAG	21 DAG	28 DAG	Mean
T1	13.08	35.00	42.00	44.67	46.00	41.91
	(3.75)	(36.24)	(40.37)	(41.91)	(42.68)	(40.31)
T2	10.91	33.33	34.67	38.67	38.00	36.16
	(3.44)	(35.23)	(36.03)	(38.41)	(38.01)	(36.94)
T3	7.50	26.67	28.33	29.67	31.00	28.91
	(2.91)	(31.06)	(32.11)	(32.95)	(33.79)	(32.50)
T4	5.00	17.00	19.67	25.67	30.67	23.25
	(2.44)	(24.30)	(26.27)	(30.36)	(33.59)	(28.67)
T5	8.50	23.67	28.67	39.67	41.33	33.33
	(3.07)	(29.04)	(32.27)	(39.00)	(39.96)	(35.11)
T6	15.16	35.67	41.00	51.67	53.67	45.50
	(4.01)	(36.63)	(39.77)	(45.94)	(47.09)	(42.37)
T7	18.41	37.33	51.67	61.33	63.67	53.50
	(4.40)	(37.64)	(45.93)	(51.54)	(52.92)	(47.00)
T8	21.50	48.67	65.67	69.33	70.67	63.58
	(4.74)	(44.21)	(54.17)	(56.43)	(57.21)	(52.96)
CD (P<0.05)	(0.14)	3.65	5.15	3.69	4.91	3.39

T1: 2nd fortnight of March, 12th SMW, DOS-20th March; T2: 1st fortnight of April, 14th SMW, DOS-3rd April; T3: 2nd fortnight of April, 16th SMW, DOS-17th April; T4: 1st fortnight of May, 18th SMW, DOS-1st May; T5: 2nd fortnight of May, 20th SMW, DOS-16th May; T6: 1st fortnight of June, 23rd SMW, DOS-5th June; T7: 2nd fortnight of June, 25th SMW, DOS-19th June; T8: 1st fortnight of July, 27th SMW, DOS-3rd July; Values in the parentheses are square root transformed value (for oviposition) and arc sine transformed value (for dead heart percentage); DOS: Dates of sowing; DAG: Days after germination significantly lower number of eggs (6.66) in 18th SMW (1st fortnight of May). Thereafter the total number of eggs per 10 plants gradually increased up to the 27th SMW (1st fortnight of July) being significantly higher (21.95) under observations period. At the initial date of sowing during 12th SMW the mean number of eggs per 10 plants was recorded to be 14.16 and there by decline to 6.66 eggs per 10 plants in 18th SMW (1st fortnight of May) over the two years of study period (Table 4). The data indicated that to escape the attack of shoot fly, 18th SMW (1st fortnight of May) was a suitable date for sowing on the basis of a number of eggs laid per 10 plants. Early sowing in March and late sowing in July, as evident from the data revealed heavy egg load of *A. soccata* population on sorghum seedlings. These findings were in agreement with Sandhu and Dhaliwal (1983), who reported that sorghum shoot fly egg load on sorghum increased from May-June. Firke and Kadam (1979) also observed that the incidence of shoot fly was low in crop sown earlier in the month of May and higher in rainy season crops.

Dead heart incidence: The dead heart incidence percentage indicated significantly lowest (17.00%) in 18th SMW (1st fortnight of May) and highest (48.67%) in 27th SMW (1st fortnight of July) at 7 DAG. The dead heart formation at 14, 21 and 28 DAG observed the same pattern with a lowest dead heart count (19.67-30.67%) in 18th SMW (1st fortnight of May) and highest dead heart percentage (65.67-70.67%) in 27th SMW (1st fortnight of July) sown crop. Overall dead heart percentage across different sowing dates revealed that a significantly lower and higher number of dead hearts was recorded in the 18th SMW (23.25%) and in 27th SMW (63.58%), respectively (Table 2). However, in the year 2019, the lowest percentage of dead heart was recorded in 20th SMW (25.41%) in contrast to 18th SMW (23.25%) as recorded in 2018 and the highest percentage of dead heart was recorded in 27th SMW (67.33%) sown crop (Table 3). The pooled mean dead heart percentage during 2018-19 indicated a high dead heart percentage (42.95%) during early sown in March. Again it was recorded high in April and afterwards, statistical decline was observed during 1st fortnight of May (18th SMW) with a significantly lower dead heart percentage (25.46%). Thereafter, the dead heart count again gradually increased up to 27th SMW (65.45%) sown crop (Table 4). These findings

Table 3. Oviposition and dead hearts due to *A. soccata* as influenced by different sowing dates during 2019

Treatment	Oviposition per 10 plants	Dead heart (%)				
		7 DAG	14 DAG	21 DAG	28 DAG	Mean
T1	15.25	40.00	43.33	45.67	47.00	44.00
	(4.03)	(39.18)	(41.14)	(42.49)	(43.25)	(41.53)
T2	12.75	37.67	39.33	37.00	39.67	38.41
	(3.70)	(37.82)	(38.81)	(37.43)	(39.01)	(38.28)
T3	9.33	23.00	26.67	37.00	36.00	30.67
	(3.19)	(28.62)	(31.07)	(37.41)	(36.82)	(33.50)
T4	8.33	21.67	29.67	30.33	29.00	27.67
	(3.04)	(27.70)	(32.97)	(33.36)	(32.55)	(31.67)
T5	8.16	20.67	24.33	27.67	29.00	25.41
	(3.02)	(26.96)	(29.46)	(31.69)	(32.56)	(30.21)
T6	17.58	33.67	51.67	54.33	57.67	49.33
	(4.30)	(35.44)	(45.94)	(47.47)	(49.41)	(44.56)
T7	19.50	45.67	56.00	60.67	62.00	56.08
	(4.52)	(42.49)	(48.43)	(51.16)	(51.92)	(48.49)
T8	22.41	49.33	69.33	74.67	76.00	67.33
	(4.83)	(44.59)	(56.39)	(59.89)	(60.65)	(55.33)
CD ($P<0.05$)	0.19	3.49	4.28	3.94	3.82	3.75

Values in the parentheses are square root transformed value (for oviposition) and arc sine transformed value (for dead heart percentage); DAG: Days after germination were in agreement with Karibasavaraja and Balikai (2006), who reported that the dead heart formation was significantly less in early sown crops and more in late sown in the rainy season. Balikai (2000) reported that shoot fly infestation began to increase in July, and reached its highest peak in August. Keerthi *et al.,* (2017) also observed that the dead heart percentage was significantly less in 24th SMW in comparison to late sowing in the month of July. Sandhu and Dhaliwal (1983) reported dead heart formation due to *A. soccata* attack was high in May-June in *kharif* season.

Correlation and regression studies: Abiotic factors like maximum temperature, minimum temperature, maximum relative humidity, minimum relative humidity and rainfall had significant effects on oviposition and dead hearts formation due to *A. soccata* infestation. The shoot fly incidence was low from 2nd fortnight of April to 2nd fortnight of May sown crop due to high temperature (>37 ˚C; maximum and > 20 ˚C; minimum), low relative humidity (< 55 %; maximum and < 25%; minimum) and low rainfall of < 20 mm as compare to other sowing week where temperature, relative humidity and rainfall proved favorable for shoot fly attack. Irregular rainfall during the experimental period played an important role in fluctuating the shoot fly incidence. High rainfall in 1st fortnight of July sown crop (>300 mm) helped to build shoot fly incidence due to increase in relative humidity and decrease in temperature during 2018 and 2019 (Table 1). From this study it was evident that both oviposition and dead heart formation by *A. soccata* had significant negative correlation with maximum temperature during 2018 and 2019. Oviposition and dead hearts had a positive correlation with minimum temperature and it was recorded non-significant during 2018-19. Further, egg load on crop and dead heart percentage had a significant positive correlation with rainfall, maximum and minimum relative humidity in 2018-19 (Table 5).

Simple regression analysis was carried out to know the most important weather factors influencing the shoot fly infestation during seedling stage. In 2018, the regression model for the estimation of shoot fly attack with respect to maximum temperature was found significant (oviposition: R^2 =0.71 and dead heart: R^2 =0.65), but it was recorded non-significant in 2019. However, the regression model for estimation

Table 4. Pooled mean oviposition and dead heart of *A. soccata* as influenced by different sowing dates over two years

Treatment	Oviposition per 10 plants	Dead heart (%)				
		7 DAG	14 DAG	21 DAG	28 DAG	Mean
T1	14.16[d]	37.5	42.66	45.17	46.5	42.95[d]
	(3.89)	(37.73)	(40.76)	(42.21)	(42.97)	(40.92)
T2	11.83[c]	35.5	37	37.83	38.83	37.29[c]
	(3.57)	(36.54)	(37.44)	(37.94)	(38.53)	(37.61)
T3	8.41[b]	24.83	27.5	33.33	33.5	29.79[b]
	(3.05)	(29.86)	(31.61)	(35.22)	(35.33)	(33.06)
T4	6.66[a]	19.33	24.67	28	29.83	25.46[a]
	(2.74)	(26.03)	(29.65)	(31.91)	(33.09)	(30.27)
T5	8.33[b]	22.17	26.5	33.67	35.16	29.37[b]
	(3.04)	(28.06)	(30.95)	(35.37)	(36.28)	(32.75)
T6	16.37[e]	34.67	46.33	53	55.67	47.41[e]
	(4.15)	(36.05)	(42.86)	(46.70)	(48.23)	(43.50)
T7	18.95[f]	41.5	56.83	61	62.83	54.79[f]
	(4.46)	(40.07)	(47.18)	(51.33)	(52.41)	(47.73)
T8	21.95[g]	49	67.5	72	73.33	65.45[g]
	(4.78)	(44.40)	(55.23)	(58.05)	(58.91)	(53.99)
CD (P<0.05)	(0.11)	4.69	5.52	6.27	5.92	4.20

Values in the parentheses are square root transformed value (for oviposition) and arc sine transformed value (for dead heart percentage); DAG: Days after germination; Means with similar letter(s) are not significantly different, analyzed by DMRT the shoot fly infestation with respect to minimum temperature was poor fitted (non-significant). Morning relative humidity had a significant effect on oviposition (R^2 =0.97 in 2018 and R^2 =0.75 in 2019) and dead hearts (R^2 =0.95 in 2018 and R^2 = 0.76 in 2019). Further, oviposition of *A. soccata* was greatly influenced by evening relative humidity with R^2 value of 0.90 and 0.83 in 2018 and 2019, respectively, but the coefficient of determination (R^2) for dead heart formation was found to be 0.89 (2018) and 0.88 (2019). Rainfall had a key role in shoot fly infestation, and the coefficient of determination (R^2) showed significant results for egg load (0.75) and dead heart (0.77) during 2018. However, in 2019 the coefficient of determination was recorded as 0.69 and 0.77 with respect to oviposition and dead hearts, respectively (Table 5).

These findings were in agreement with the results of several workers (Katole and Mundiwale, 1992; Shekar, 1995; Singh and Verma, 1988; Somasekhar, 1985; Venkatesh and Balikai, 2002), who observed significant negative correlation with maximum temperature and significant positive correlation with relative humidity. Moreover, the role of temperature in form of degree day concept has been used to monitor and predict pests (Singh *et al*. 2009; 2017) in Indian region. Keerthi *et al.* (2017) found that rainfall had a non-significant positive relationship with shoot fly oviposition and a significant positive association with dead heart. Karibasavaraja and Balikai (2006) reported a positive association between egg load and dead hearts with rainfall. Kumar *et al.* (2015) reported that rainfall had negative association with egg laying and dead hearts formation, had positive association with temperature (maximum and minimum) and relative humidity (maximum and minimum). However, the present results were contradictory to the findings of Aghav *et al*. (2007), Dubey and Yadav (1980) and Nair *et al.* (1995), who reported a positive correlation with maximum temperature due to high relative humidity and irregular rainfall pattern. Rai and Wakgari (2012) reported positive relationship of maximum temperature with egg load which might be due to variation in temperature between two regions, the temperature ranged from 3.1˚C to 24.1˚C in Ethiopia whereas in Ludhiana location it was varied between 18.16˚C to 40.48˚C. Heavy rainfall had negative association with sorghum shoot fly, *A. soccata* attack due to substantial mortality among adults (Delobel, 1984).

Table 5. Correlation and simple regression studies for oviposition and dead heart percentage with weather parameters in 2018 and 2019

Weather parameters	Oviposition 2018	R^2 value	R value	Oviposition 2019	R^2 value	R value
Oviposition						
Maximum Temperature	Y= -1.98 MaxT + 85.14	0.71**	-0.84**	Y= -1.27 MaxT + 60.86	0.46	-0.67
Minimum Temperature	Y= 0.71 MinT- 4.75	0.14	0.38	Y= 0.66 MinT – 1.53	0.18	0.42
Maximum RH	Y= 0.41 MaxRH - 13.80	0.97**	0.98**	Y= 0.35 MaxRH – 8.94	0.75*	0.86**
Minimum RH	Y= 0.30 MinRH + 1.25	0.90**	0.95**	Y= 0.27 MinRH + 4.30	0.83**	0.91**
Rainfall (RF)	Y= 0.03 RF + 8.14	0.75**	0.86**	Y= 0.04 RF + 10.63	0.69**	0.83**
Dead heart						
Weather parameters	**Dead heart 2018**	**R^2 value**	**R value**	**Oviposition 2019**	**R^2 value**	**R value**
Maximum Temperature	Y= -4.47 MaxT + 204.86	0.65*	-0.81*	Y= -3.58 MaxT+174.09	0.50	-0.70
Minimum Temperature	Y= 1.79 MinT -2.26	0.16	0.40	Y= 1.81 MinT – 0.54	0.18	0.42
Maximum RH	Y= 0.96 MaxRH – 20.29	0.95**	0.97**	Y= 0.98 MaxRH -21.04	0.76**	0.87**
Minimum RH	Y= 0.70 MinRH + 14.40	0.89**	0.94**	Y= 0.76 MinRH +14.70	0.88**	0.93**
Rainfall (RF)	Y= 0.08 RF + 30.40	0.77**	0.87**	Y= 0.12 RF + 32.19	0.77**	0.87**

Correlation was significant *(P<0.05) and **(P<0.01); R^2: Coefficient of determination; R: Correlation coefficient

Table 6. Plant growth parameter as influenced by different sowing dates due to damage of *A. soccata*

Treatment	Plant height (m)			Stem girth (mm)			Yield (q/ha)*		
	2018	2019	Mean	2018	2019	Mean	2018	2019	Mean
T1	1.66	1.56	1.61	16.04	15.88	15.96	377	374	376
T2	1.71	1.64	1.67	15.87	15.81	15.84	390	395	392
T3	1.73	1.67	1.70	15.82	15.13	15.48	408	400	404
T4	1.80	1.82	1.81	14.77	14.67	14.72	412	407	409
T5	1.64	1.51	1.57	16.09	14.98	15.54	386	410	397
T6	1.47	1.46	1.46	16.30	16.20	16.25	349	341	345
T7	1.43	1.38	1.40	16.36	16.21	16.28	324	315	319
T8	1.30	1.28	1.29	16.45	16.58	16.51	304	301	302
CD (P<0.05)	0.21	0.07	0.10	NS	1.08	0.79	7.85	5.36	3.59

*10 quintals (q) = 1 ton

Growth parameters and forage yield: Maximum plant height was observed in crops sown during the 18th SMW (1.80 m) and minimum in 27th SMW (1.28 m) during 2018 (Table 6). The same pattern was also recorded during 2019. The mean average plant height over the two years of study period revealed that the tallest plants were observed in sowing date of 1st week of May (1.81 m). The crop sown during 3rd week of March (12th SMW) had a plant height of 1.61 meters and thereafter, it gradually increased to 1.81 meter in 18th SMW, after that due to heavy infestation of shoot fly plant height tend to decrease in 1st fortnight of July (1.29 m).

The highest and lowest stem girth was recorded in 27th SMW (16.45 mm) and 18th SMW (14.77 mm) sown crop, respectively in 2018. A similar trend was observed in 2019. Pooled analysis revealed that minimum stem girth was recorded in the 18th SMW sown crop (14.72 mm), and it was at par with the crop sown during the period of sowing from 14th to 16th SMW. However, after 18th SMW the stem girth started to increase with the passage of time and recorded to be maximum in 27th SMW (16.51 mm). The trend of increase in the stem girth during the rainy season might be due to favorable growth conditions and comparatively less plant population owing to heavy shoot fly incidence recorded during period of observation (Table 6). The data on plant growth parameter and yield of crop were in agreement with the results of Ameta and Sumeria (2004), who observed that plant height, weight, length of ear head, stover yield, number of primaries and spikelets were adversely affected by shoot fly, stem borer and other pest attack. Karhale *et al.*(2014) recorded that early sown crop (24th SMW) had more plant height, number of leaves, leaf area and dry matter as compared to 25th SMW.

The range of green forage yield (GFY) varied from 304 to 412 q/ha with the maximum yield recorded in 18th SMW (1st fortnight of May) sown crop (412 q/ha) and minimum (304 q/ha) in 27th SMW (1st fortnight of July). However in the year 2019, maximum GFY was recorded in 20th SMW due to low shoot fly pressure (410 q/ha) and minimum in 27th SMW (301 q/ha). The pooled mean of GFY revealed that the highest yield was obtained in 18th SMW. Thereafter with the advancement in date of sowing, the yield tended to decline with minimum GFY (302 q/ha) as recorded for the crop sown in July month during 27th SMW. Initial date of sowing (12th SMW) recorded 376 q/ha yield, thereafter increased up to 409 q/ha in 18th SMW and after that it declined up to 302 q/ha in 27th SMW sown crop (Table 6).

Conclusion

Keeping in view the availability of quality green fodder and safety of dairy animals and pesticide use, it was concluded that 1st fortnight of May (18th SMW) was the best time for planting of sorghum to escape from shoot fly (*Atherigona soccata*) attack as compared to other sowing periods. Climactic factors revealed that high temperature, low relative humidity and low rainfall helped to reduce the attack of shoot fly during 18th SMW (1st fortnight of May) and low temperature, high relative humidity and high rainfall during 2nd fortnight of June (25th SMW) and 1st fortnight of July (27th SMW) was found to be favorable for shoot fly incidence in terms of both oviposition and dead heart. Further it was it was supported by the highest green fodder yield during 18th SMW sown crop. Hence, it could be served as non-chemical method to reduce the damage caused by shoot fly during the seedlings stage by the modification of sowing period under Punjab conditions

Acknowledgment

The authors are thankful to All India Coordinated Research Project (AICRP) on Sorghum for providing funds and necessary technical supports for carrying out this investigation.

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