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RESEARCH ARTICLE

IMPACT ASSESSMENT OF DIFFERENT SOWING DATES ON MAIZE APHID, *Rhopalosiphum madis* INFESTATION IN BANGLADESH

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ABSTRACT

Maize (*Zea mays* L.) is attacked by many insect-pests which are the principal limiting factor for its productivity all over in Bangladesh. The maize aphid, *Rhopalosiphum maidis* is one of the most destructive pests of maize as second important cereal crop after rice. The present investigation was set up at the Entomology Field Laboratory, Department of Entomology, Bangladesh Agricultural University (BAU), Mymensigh during Rabi season of 2016-17 in order to assess the impact of different sowing date on maize aphid infestation under field condition and it's also effect on morphological, phenology, yield attributes and yield of maize. The experiment was laid out in randomized complete block design (RCBD) having three replications. Maize *var.* BARI Hybrid Butta-09 variety was used as experimental crop. Nine sowing dates viz. 3rd(S_1) & 4th(S_2) week of October, 1st(S_3), 2nd(S_4), 3rd(S_5) & 4th(S_6) week of November and 1st(S_7), 2nd(S_8) & 3rd(S_9) week December were used as treatments. To assess the impact of different sowing dates, different data were collected from randomly selected five plants from each replicated plots at different growth stage i. e. vegetative, inflorescence and cob formation stage at least three times based on three main parameters such as entomological features (healthy & infested plants, inflorescences & cobs; body length(mm), number of aphid per plant and inflorescence), morpho-physiological characters (Plant height, cm) and yield attributes & yield (number of cob plant^{-1}, cob length without husk (cm), diameter of cob without husk (cm), number of grain cob^{-1}, grain weight cob^{-1}(g) and grain yield, t ha^{-1}). The results revealed that 1st week of November (S_3) as sowing date was found the best for suppressing the maize aphid, and morpho-physiological characters, yield attributes and grain yield was also the best compared to others sowing dates due to ensuring the lowest percentage of infested maize plant at vegetative stage (36.91%), inflorescence stage (43.12%), cob formation stage (20.53%) & average the lowest percentage of infested maize (33.52%), and the highest plant height (223.66cm), number of cob plant^{-1} (1.73), cob length without husk (23.23cm), diameter of cob without husk (16.17cm), number of grain cob^{-1} (641.21), grain weight cob^{-1}(235.16) and maximum grain yield (10.56 t ha^{-1}). Furthermore, based on average aphid infestation, the increasing order of infestation due to different sowing date were S_4<S_9<S_1< S_2< S_7< S_8< S_5< S_6, and thereby to yield, the increasing order of yield were S_4<S_5<S_6< S_7< S_8< S_9< S_2< S_1. Besides, a matter of correlation between different parameters, considering to the different sowing dates, average aphid infested plants (%) and yield of maize; firstly, the present study showed that strongly significant positive correlation was found between sowing dates with aphid infested plants, and secondly, very strongly significant negative correlation between sowing dates & grain yield of maize, and finally, very highly significant negative correlation was observed between average infested plants (%) with grain yield of maize. Henceforth, on the basis of body length, among different growth stages of maize production, the minimum (2.10mm) body length of aphid was recorded at inflorescence stage than vegetative (2.32mm) and cob formation stage (2.51mm), which is why; less damage of pollen as well as produced higher yield. On the other hands, based on body size, among the different sowing dates, the tolerable body length (2.34mm) was found sown on 1st week of November where the highest yield occurred than others sowing dates due to less damage of pollen as well as occurred maximum fertilized of pollen. However, considering the incidence of aphid, among different sowing dates, the minimum tolerable no. of aphid per plant (280) and inflorescence (470) was recorded sown on 1st week of November where the maximum grain yield occurred than others sowing dates. Sowing date of 1st week of November (S_3) was the best because all environmental factors are more suitable for producing of maize and suppressing or combat against aphid as well as yield with better quality. In addition, we have also found that the sowing date of 2nd week of November (S_4) performed second best. Therefore, considering all facts, 1st week of November as sowing date could be recommended to the maize grower for the most effective for suppressing the maize aphid, *R. maidis*. Hence, in addition, 2nd week of November could also be suggested for second best effective sowing date for suppressing incidence of aphid where second crop of cropping pattern is not available or not apply in the field.

KEYWORDS

Sowing dates, *Rhopalosiphum maidis*, Maize infestation, Morpho-physiological characters, Yield attributes.

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1. Introduction

The maize aphid, *Rhopalosiphum maidis* is the most important pests infesting maize crop in Bangladesh. This aphid, *R. maidis* was first described by Fitch, 1856. The pest could become a treat to the early as well as late maize cultivation in Bangladesh. About 342 to 421.7 aphids per plant are attack maize (Fareed, 1991). In a study stated that about 98.66 to 202.55 aphids per plant in mild summer (Mishwani and Karimullah, 1990). More than 250 species of insects which were associated with maize in the field and storage conditions (Mathur, 1987). Of these, 74 species have appeared recently and about a dozen were of potential economic importance. Among them maize aphid is the most important constraint to corn production because, the larva of *R. maidis* is a major agricultural pest and polyphagous in nature (Alam et al., 2014). The larvae also feed on all parts of plant. Aphid infestation in maize, it causes damage in pollination and introduces various bacteria, virus and fungi on leaf, cob and plants. As a result, it causes loss of yield ranged 8-12% annually in maize (Alam et al., 2020a).

In Bangladesh, aphid could become more incidences on maize in mid-February to early March of Rabi season (Alam et al., 2014). He also reported that probably temperature is the most important physical factors-influencing the rate of aphid development and reproduction. It causes damage to maize and other plants belongs to the grass family. The yield of maize crop is adversely affected due to insect pests, disease, weeds, nematodes and birds etc. Heavily aphid infested maize leaves may wilt, curl, and show yellow or even dead patches. Tassels and silks may be covered with honeydew. Aphids' infestation may result in about 40 percent of the heavily infested stalks (Alam et al., 2019a, b). In Bangladesh, maize (*Zea mays* L.) is the second most important cereal crops after rice both in terms of area and production (Alam et al., 2020a, b). Its production in Bangladesh is about 3.3 MT annually in 2018-2019 (BBS, 2020).

The productivity of maize is very low compared to that of neighboring countries. But, more than 90% of the home grown maize is feeding a bourgeoning poultry and fish feed industry, and rests are used as human food (Alam et al., 2019a, b, 2018). That's why; it is increasingly raising an important position in crop husbandry because of its higher yield and short growth duration. In addition, it is a rich source of food and fodder nowadays in for rearing of poultry and fish. Maize is also used in industries for manufacture of corn sugar, oil, protein, corn-flacks, soup, salad and corn syrup etc. This demand should be meet up by increasing yield of maize. For obtaining optimum production, seed must be sown on proper time so that aphid infestation may be minimum or not. Yield loss due to aphid infestation occur if the crop sown to early or late (Sanp and Singh, 2018). As in known, it is the matter of worried that maize production is hindered by aphid infestation. Out breaks of this aphid occur in the early or late growing season, while maize tassel or inflorescences appear.

At this time, maize grower usually uses a lot of insecticides indiscriminately and frequently for controlling aphid to achieve a high yield. As in known, insecticides applications have several harmful influences such as environmental, agro-ecosystems pollution, causes health hazard to human as well as financial issues, outbreak of secondary pests, development of resistance to insecticides and contamination of food and eco-system (Alam et at., 2020, 2019a, b). Therefore, to skip the environment pollution and safe eco-system through suppressing the infestation of aphid, scientists are endeavoring to find out the alternative safe procedures for controlling aphid in the maize field, which don't have such negative impacts on the environments.

Performance of maize yield is not only depends on successive sowing dates but also minimum aphid infestation. In generally, so little is known about the physiology of maize plants in relation to aphid infestation. So, proper sowing dates with low incidences of aphid are essential issue for producing maize and them correlation. That's why; to get optimum yield, maize crop must be sown at proper time to suppress the aphid infestation where yield will be high with the produce safety food and eco-system. Keeping in view above scenario, the present experiment was conducted with the objective to assess the impact of different sowing dates on percent infestation of maize aphid with respect to crop morpho-physiological characters, yield attributes and yield.

2. Materials and Methods

2.1 Location of experimental site and experimental duration

The research experiment was conducted on maize at Entomology Field Laboratory under Department of Entomology, Bangladesh Agricultural University (BAU), Mymensingh during Rabi season of 2016-17 in order to know the best sowing date of maize production instead of low aphid infestation where, maximum yield will be produced. The research site was situated at 24.75 N latitude and 0.50 E longitudes at an average altitude of 18m above the mean sea level. The site of experiment belongs to the Sonatola series of the dark grey floodplain soil type under Old Brahmaputra Floodplain Agro-Ecological Zone (AEZ-9) (Alam et al., 2019a, b; 2020a, b).

2.2 Soil properties

Initial soil samples were collected randomly from each replication of respective experimental field using shovel from 0 to 15cm before application of FYM and chemical fertilizers. Then the collected samples were air dried, grounded and made fine. Finally, analysis was done through using Soil Kit-Box method. The field was a medium high land with well drained silty-loam texture (Table 1).

Table 1: Physio-Chemical properties of soil

Experimental sites	pH	OM (%)	Total N(%)	(meq/100g soil)	(ug/g soil)			
				K	P	S	Zn	B
BAU Campus	6.5	1.67	0.082	0.044	8.92	26.73	1.33	0.31

2.3 Weather data

The condition of climate in Bangladesh was moderately cold and high humid with frequent wind during maize cultivation. Monthly mean weather data was recorded during the crop growing season from July 2016 to June 2017. The mean maximum temperature 30^{0}C and minimum temperature 18^{0}C were recorded. Maximum temperature ranged from 25.5^{0}C to 30^{0}C. The minimum temperature ranged from 18^{0}C to 23.4^{0}C. Similarly, relative humidity ranged from 75% to 87%. The highest rainfall (522.7mm) and the lowest rainfall (0.00mm) were recorded. The maximum sunshine of 204.8hrs and the minimum sunshine of 84.70hrs were recorded in the time of crop season. The detail information of weather data were depicted in Table 2 (Alam et al., 2020a).

Table 2: Details of weather data at the experimental site

Months	Average Temperature (^{0}C)			Relative Humidity (%)			Average rainfall (mm)	Total sunshine (hrs.)
	Maxi.	Min.	Mean	Maxi.	Min.	Mean		
January	23.5	12.0	18.0	97.0	56.0	84.0	18.20	84.70
February	27.8	16.8	22.3	96.0	52.0	80.0	4.000	137.8
March	31.0	20.1	25.5	94.0	52.0	75.0	104.8	190.2
April	32.4	24.3	28.4	92.0	65.0	81.0	25.60	171.2
May	32.0	23.7	27.9	93.0	65.0	81.0	331.1	165.3
June	32.7	26.2	29.5	94.0	70.0	84.0	388.8	149.5
July	31.6	26.5	29.1	95.0	74.0	87.0	522.7	101.8
August	33.2	26.8	30.0	92.0	66.0	81.0	97.60	179.6
September	32.0	26.1	29.1	95.0	73.0	87.0	408.6	125.6
October	32.4	24.2	28.3	96.0	64.0	84.0	31.70	200.9
November	29.5	18.1	23.4	97.0	52.0	81.0	1.000	204.8
December	27.5	14.6	21.1	97.0	48.9	81.4	0.000	180.3

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2.4 Experimental design, materials and treatments details

The experiment was laid out in randomized complete block design (RCBD) having three replications. Total number of experimental plots was 27. Maize *var.* BARI Hybrid Butta-09 variety was used as experimental crop. The experiment consisted of nine (09) dates of sowing were scheduled as treatments *viz.* 3rd & 4th week of October, 1st, 2nd, 3rd & 4th week of November and 1st, 2nd & 3rd week of December of Rabi season, 2016-17. The details of nine sowing dates are depicted in the Table 3.

2.5 Plot size, design and crop sowing

The crop was sown according to nine mentioned sowing dates as treatments wise in the experimental fields with a plot size of 10m^2 (4m×2.5m), spacing of 60×30cm between row to row and plant to plant, respectively, and the distance was 70cm between the two plots. Five (05) plants were taken from each plot as sample. Seed sowing was done using manual practice after final land preparation. Seeds were treated with Bavistin@2g/kg of seeds one day prior of sowing. Before sowing, seeds were soaked in water over night for easy germinating in every mentioned sowing time.

Table 3: Details of sowing dates as treatments tested against maize aphid, R. maidis

Sowing dates as weekly wise of month	Seasonal status	Symbol of sowing dates	Name of months	Sowing dates as weekly wise of month	Seasonal status	Symbol of sowing dates	Name of months
3rd week	Early	S_1	October, 2016	1st week	Late	S_7	December, 2016
4th week		S_2		2nd week	Very Late	S_8	
1st week	Timely	S_3	November, 2016	3rd week		S_9	
2nd week		S_4					
3rd week		S_5					
4th week	Late	S_6					

2.6 Crop husbandry

The land was ploughed through six (06) cross ploughing using mini power tiller to bring the soil under good tilth 15 days prior of seed sowing. The FYM@ 8kg/plot area (10m^2) was applied in all experimental plots and it was uniformly incorporated into the soil during the first land preparation. Besides, the others fertilizers were used properly. Before final ploughing, all fertilizers were applied during land preparation except urea and Muriate of Potash (MOP). One-fourth of urea and MOP were applied at the time of final land preparation. The nitrogen, phosphorus, potassium, sulphur, mangnishium, zinc and boron fertilizers were applied in form of urea, triple super phosphate, muriate of potash, gypsum, magnesium sulphate, zinc sulphate and boric acid at the rate of 250, 80, 120, 45, 8, 3 and 2.4 kg ha^{-1}, respectively (FRG, 2012, Alam, et al., 2019b, 2020a, b). The seed rate of maize was 20kg per hectare. The seed of maize (BARI Hybride Butta-09) was sown according to experimental scheduled sowing dates in line with raise. Remaining urea and MOP were applied three equal installments at pre-vegetative stage, full vegetative stage and early corn formation stage. Firsthand weeding and earthing up were done at 45 days after sowing (DAS). After that secondhand weeding were performed at 75DAS. Irrigation and other intercultural operation were done properly as and when necessary for better growth and development of maize. Harvesting was carried out in 145 days after respective tested sowing manually.

3. Observation Recorded

To assess the impact of different sowing dates, healthy and infested plants, inflorescences & corn were identified and counted from randomly selected five plants from each replicated plots at different growth stage i. e. vegetative, inflorescence and cob formation stage. Data was collected from three mentioned stages from each replication at least three times i.e. when aphid population was sufficient, low and high. The whole grain was harvested when 95% of the cobs became matured in plants. The harvested cobs were then threshed, cleaned and dried to moisture content of 12-15%. The grain yield was received from each replication of each treatment, were weighed and recorded, and data were converted into yield per hectare according to each replication of treatment. All data of all stages were collected and compiled into average value. Plant height (cm), cob length (cm) without husk and diameter of cob without husk were measured from five randomly selected plants in each plot (replication) from the middle portion by measuring tape stretching.

They were measured in centimeters and averaged. Number of cobs and grain in the five (05) randomly selected plants and cobs was counted from each replication of treatment after harvest, respectively. After shelling the grain from cobs and were divided by the number of cobs. Then all grains received from each replication were weighed and on the basis of grain yield per plot, grain yield per hectare was calculated in kilograms by using digital weight machine. Body length of aphid was measured by using mile-meter graph paper and the data were compiled according to sowing dates. During observation, different data were collected based on three main parameters such as entomological features (healthy & infested plants, inflorescences & cobs; body length(mm), number of aphid per plant and inflorescence), morpho-physiological characters (Plant height, cm) and yield attributes & yield (number of cob plant^{-1}, cob length without husk (cm), diameter of cob without husk (cm), number of grain cob^{-1}, grain weight cob^{-1}(g) and grain yield, t ha^{-1}). The percentage infestation of the plant due to attach of maize aphid was calculated by using the following formula (Alam et al., 2020b, 2019b):

Infestation of plant (%)

$$=\frac{\text{Total number of plants per plot}-\text{total number of healthy plants per plot}}{\text{Total number of plants per plot}}\times 100$$

Grain yield (kg/ha) at 15% moisture content was calculated using fresh grain weight with the help of the below formula (Alam et al., 2020a):

$$\text{Grain yield } (\frac{\text{Kg}}{\text{ha}})=\frac{\text{F.W. } (\frac{\text{kg}}{\text{Plot}})\times(100-\text{HMP})\times\text{S}\times 10000}{(100-\text{DMP})\times\text{NPA}}$$

Where, F.W= Fresh weight of grain in kg per plot at harvest; HMP=Grain moisture percentage at harvest; DMP=Desired moisture percentage i.e. 15%; NPA= Net harvest plot area (m^2) and Shelling co-efficient i.e. 0.8. This formula was also adopted to adjust the grain yield (kg/ha) at 15% moisture content. This adjusted grain yield (kg/ha) was again converted to grain yield (t/ha) (Alam et al., 2020a).

4. Statistical Analysis

All experimental data were recorded, tabulated, processed and complied for statistical analysis through using Microsoft Excel 2010. Before statistical analysis, the data obtained was transformed to arc sine transformation. The obtained data were statistically analyzed to find out the significance of differences among the treatments. The mean values of all the characters were evaluated and analysis of variance (ANOVA) following Randomized Complete Block Design was performed by using R statistics software version 3.5.3 to find out the treatment effect, and the mean differences were adjudged by Duncan's Multiple Range (DMRT) Test (Gomez and Gomez, 1984). Relation of variables with different sowing dates, aphid infested plant and yield of maize was calculated by using Pearson's Correlation Coefficient and Multiple Regression analysis with the help of R statistics software version 3.5.3. All graphs were made up by Microsoft Excel worksheet 2010.

5. Results and Discussion

Nine (09) sowing dates namely 3rd & 4th week of October, 1st, 2nd, 3rd & 4th week of November and 1st, 2nd & 3rd week of December of Rabi season, 2016-17 were assessed the impact for suppressing aphid, *R. maidis* at the Entomology Field Laboratory, Bangladesh Agricultural University (BAU), Mymensingh-2202. Their effect was observed at three stages during maize cultivation. Observations were made on the mean percent infestation of plants, inflorescences & cobs, entomological features, morpho-physiological characters and yield attributes & yield of maize as influenced by different sowing dates and their results are presented below in Table 4, 5, 6, 7 & 8 and Figure 1.

5.1 Effect of different sowing dates on the percent infestation of aphid at different stages

The effect of different sowing dates was observed up to cob formation after different sowing dates of maize. It was found that the application of sowing dates showed significant (P≤0.01 and P≤0.05) mean percent plant infestation during maize production (Table 4). The mean percentage of plant infestation was recorded in the range of 20.53 to 83.25 from vegetative growth stage to cob formation stage. The results clearly revealed that different sowing date had a significant impact on the plant infestation for suppressing aphid and the effect was also clearly climate and temperature dependent.

5.1.1 Vegetative stage

The results showed that the aphid's infestation started at the vegetative stage and continued to the cob formation stage. From the Table 4, it showed that the minimum infestation was recorded in plots sown on 3rd week of October (S_1) with percent plant infestation of 30.12 followed by 32.85%, 36.91%, 39.78%, 42.65%, 55.93%, 64.27% and 68.14% in S_2, S_3, S_4, S_9, S_5, S_6 and S_7, respectively, whereas the maximum (72.39%) and significantly (P≤0.01) higher plant infestation was found in S_8 (2nd week of December). The findings are supported by some researchers (Buriro et al., 2015; Chander et al., 2016). They said that, the incidence of aphid is more at the vegetative stage due to more succulent when maize sown on early or very late. The condition of climate is more suitable for increasing aphid population.

5.1.2 Inflorescence stage

The data revealed that the infested plants as affected by aphid on different sowing dates were significant (P≤0.05) different (Table 4). During inflorescence stage, 1st week of November (S_3) sown crop had a minimum percentage of infested maize plants that differed significantly from other sowing dates. The latter, however, being at par with the 2nd week of November (S_4) sown date crop. Sowing dates significantly influenced on aphid population on the crop i. e. the effect of sowing dates on infested maize plants was significantly differed during inflorescence stage. Hence, the highest (83.25%) percent of infested plant was occurred as affected by aphid in 3rd week of November (S_5).

Quantum of peak infested maize plant was recorded among nine sowing dates, and it was also maximum infested plants among three stages. Similar type of result was found (Anwar et al., 2011; Chander et al., 2016). They reported that timely sown crop harbored fewer aphids on inflorescence than early, late and very late season due to decline the temperature, unfavorable climate and the prevalence of predators which is the barrier for multiplication of aphid. Besides, inflorescence is the vital for production of yield because yield decreases due to increase of aphid infestation at that stage. Aphids might prefer late and very late sown crops owing to their more succulence of plant than timely sown crop. So, less incidence of aphid was occurred in inflorescence and cob formation stage if the seed sown on timely.

5.1.3 Cob formation stage

The results depicted in the Table 4 revealed that all sowing dates proved significantly suppress aphid population. The percent of infested plant differed significantly at the 5% level of probability among different sowing dates at the cob formation stage. The minimum (20.53%) percentage of aphid infested plants was observed on the crop sown on 1st week of November (S_3) which was significantly superior over the rest dates of sowing. But it was statistically similar to S_4 (23.04%) and S_9 (25.31%). The maximum (66.22%) percentage of aphid infested plant was recorded on the crops sown on the 4th week of October (S_2) followed by S_1(63.03%), S_7 (53.54%), S_8(50.26%), S_6(41.32%) and S_5(38.96%), respectively (Table 4) (Chander et al., 2016; Buriro et al., 2015). They stated that, aphid incidence and damage are limited at sowing timely (timely season) than early, late and very late season. Hence, reproductive stage i.e. cob formation phase is not affected by aphid due to plant and cob become hard (no succulent) than vegetative and inflorescence phage.

Table 4: Effect of different sowing dates on aphid infestation of maize at different growth stages during Rabi season, 2016-2017

Sowing dates	Symbol of sowing dates	Mean percentage of infested maize plants at			
		Vegetative stage	Inflorescence stage	Cob formation	Average
3rd week of October	S_1	30.12gh	37.50ghi	63.03a	43.55ef
4th week of October	S_2	32.85g	39.61g	66.22a	46.23e
1st week of November	S_3	36.91f	43.12f	20.53e	33.52h
2nd week of November	S_4	39.78e	45.30f	23.04e	36.04g
3rd week of November	S_5	55.93d	83.25a	38.96d	59.38b
4th week of November	S_6	64.27c	81.37abc	41.32d	62.32a
1st week of December	S_7	68.14ab	46.98e	53.54b	56.22bcd
2nd week of December	S_8	72.39a	49.01d	50.26bc	57.22bc
3rd week of December	S_9	42.65e	41.34f	25.31e	36.43g
Level of significance		**	*	*	*
CV (%)		6.25	7.63	6.02	7.23
LSD		3.88	2.00	3.29	1.23
SE (±)		1.22	1.04	1.13	0.98

In column, means followed by different letters are significantly different, *means at 5% level of probability, **means at 1% level of probability, CV= Coefficient of variation, LSD= Least significant difference, SE (±) = Standard error

With a view of overall average percent of infested plant of the observations from vegetative to cob formation stage, the minimum (33.52%) percentage of aphid infested plants was found on the crop sown on 1st week of November (S_3) which was followed by 36.04%, 36.43%, 43.55%, 46.23%, 56.22%, 57.22% and 59.38% in S_4, S_9, S_1, S_2, S_7, S_8 and S_5, respectively, whereas the maximum (62.32%) and significantly (P≤0.01) higher plant infestation was found in S_6 (4th week of November) (Anwar et al., 2011; Sanp and Singh, 2018).

5.2 Morpho-physiological characters

5.2.1 Plant height (cm)

The results of analysis of variance from this study showed that plant height of maize varied significantly (P≤0.05) due to the effect of different sowing dates (Table 5), where maximum (223.66cm) plant height was noted sown on 1st week of November (S_3), whereas the minimum (198.74cm) plant height was observed from the date of sowing on 3rd week of October (S_1) which confirms the finding (Buriro et al., 2015). The early and late sowing had significant effect on plant stature, where plants with decreased height were obtained by sowing of maize earlier as compared to 1st and 2nd week of November planting.

5.3 Yield attributes characters and yield

Yield attributes and yield namely the number of cob plant^{-1}, cob length without husk, diameter of cob without husk, number of grain cob^{-1}, grain weight cob^{-1} and grain yield had differed significantly (P≤0.05 and P≤0.01) among the different dates of sowing in the present study. The result of the effect of different sowing dates on yield attributes and yield is depicted in Table 5.

5.3.1 Number of cob per plant

As the results showed, there were significant differences among the different dates of sowing at 1% level of probability (Table 5). The highest (1.73) no. of cob plant^{-1} was obtained from 1st week of November (S_3), which was found at par with S_4 (1.70). They were followed by 1.45, 1.40, 1.20, 1.15, 1.10 and 1.05 in S_5, S_6, S_7, S_8, S_9 and S_2, respectively. The lowest (1.00) no. of cob plant^{-1} was recorded in S_1 (Maryam et al., 2011). They stated that, sown on mid-November had maximum number of cob per plant.

Table 5: Morpho-physiological characters, yields attributes and yield of maize as affected by different sowing dates against aphid, R. maidis during Rabi season, 2016-2017

Treatments	SD	Plant height (cm)	No. of Cob plant^{-1}	Cob length without husk (cm)	Diameter of cob without husk (cm)	No. of grain cob^{-1}	Grain wt. cob^{-1} (g)	Grain Yield (t ha^{-1})
3rd week of October	S_1	198.74gh	1.00f	14.52g	11.13h	366.73f	130.28h	5.63g
4th week of October	S_2	201.23g	1.05f	15.14fg	11.60fg	371.98f	135.97g	5.85f
1st week of November	S_3	223.66a	1.73a	23.23a	16.15a	641.21a	235.16a	10.56a
2nd week of November	S_4	220.12b	1.70a	23.00ab	16.07ab	605.67b	210.30b	10.24b
3rd week of November	S_5	217.34cd	1.45ab	20.01c	15.10c	530.14c	180.04c	9.95c
4th week of November	S_6	213.07d	1.40bc	18.35d	13.86d	500.85c	172.51cd	9.86c
1st week of December	S_7	210.84de	1.20cd	18.00de	13.24e	450.39d	160.09e	7.94d
2nd week of December	S_8	208.29e	1.15d	17.20e	12.77ef	420.51e	153.47f	7.02e
3rd week of December	S_9	205.41f	1.10e	16.57ef	12.00f	400.42e	142.72g	6.00f
Level of significance		*	**	*	*	**	*	*
CV (%)		6.35	8.44	5.17	7.62	6.87	5.65	6.70
LSD		2.25	0.08	0.22	0.42	21.53	8.01	0.17
SE (±)		1.23	1.11	0.95	1.30	0.79	1.14	1.01

In column, means followed by different letters are significantly different, *means at 5% level of probability, **means at 1% level of probability, CV= Coefficient of variation, LSD= Least significant difference, SE (±) = Standard error, SD= Symbol of sowing dates

5.3.2 Cob length

In this study sowing dates significantly (P≤0.05) affected on length of cob without husk (Table 5). The length of cob without husk was recorded in the range of 14.52 to 23.23cm. Among the different sowing, the maximum (23.23cm) length of cob without husk was found in 1st week of November (S_3) followed by S_4(23.0cm), S_5(20.01cm), S_6(18.35cm), S_7(18.0cm), S_8(17.20cm), S_9(16.57cm) and S_2(15.14cm), respectively, whereas the minimum (14.52cm) cob length was obtained sown on 3rd week of October (S_1). The results are in line with the findings of Sanp and Singh, 2018. In this study, 1st week of November had highest cob length whereas from sown on mid-December minimum cob length was obtained.

5.3.3 Cob Diameter

The experimental result revealed that the effect of all the dates of sowing had highly significant (P≤0.05) influence on the diameter of cob without husk (Table 5). However, the longest (16.15cm) diameter of cob was noted sown on 1st week of November (S_3), while the shortest (11.13cm) was found grown on 3rd week of October (S_1). The results of the present study are also similar to the finding of the study (Sanp and Singh, 2018). They reported that cob diameter directly increases with low infestation of plant by aphid during production of maize.

5.3.4 Number of grain per cob

From the result showed, in Table 5, there were significant different at 1% level of probability among the different dates of sowing. Henceforth, number of grain cob^{-1} was significantly influenced by various sowing dates. Highest (641.21) number of grain cob^{-1} was obtained sown on 1st week of November (S_3), which was followed by S_4(605.67), S_5(530.14), S_6(500.85), S_7(450.39), S_8(420.51), S_9(400.42) and S_2(371.98), respectively whereas the smallest (366.73) number of grain cob^{-1} was observed sown on 3rd week of October (S_1) (Anwar et al., 2011).

5.3.5 Grain weight per cob

The results of this study showed that there were significant differences among the different dates of sowing at 5% level of probability (Table 5). The maximum (235.16g) grain weight cob^{-1} was got from 1st week of November (S_3), which was followed by 210.30g, 180.04g, 172.51g, 160.09g, 153.47g, 142.72g and 135.97g in S_5, S_6, S_7, S_8, S_9 and S_2, respectively. The minimum (130.28g) grain weight cob^{-1} was recorded in S_1. This result agrees with the finding by Gurung et al., 2018 that optimum planting dates resulted in higher grain weight per cob than early and late planting dates because of higher cob numbers and greater grain number per plants.

5.3.6 Grain yield

In the present study, from the Table 05, a significant variation in grain yield of maize was found under various sowing dates at 5% level of probability. Maximum (10.56 t ha^{-1}) grain yield was observed sown on 1st week of November (S_3) followed by S_4(10.24 t ha^{-1}), S_5(9.95 t ha^{-1}), S_6(9.86 t ha^{-1}), S_7(7.94 t ha^{-1}), S_8(7.02 t ha^{-1}), S_9(6.0 t ha^{-1}) and S_2(5.85 t ha^{-1}), respectively. However, minimum (5.63 t ha^{-1}) grain yield was noted sown on 3rd week of October (S_1) (Gurung et al., 2018; Anwar et al., 2011; Chander et al., 2016; Buriro et al., 2015). They reported that the maximum grain yield was obtained from the 1st week of November sowing dates because of less incidence of aphid and minimum damage of grain. Reproduction and damage occurred by aphid depends on climatic factors, it could be deduced that less than 6^{0}C and more than 24^{0}C did not favour the aphid multiplication on maize i.e. temperature between 7-25^{0}C was found to favour the multiplication of aphid (Wains et al., 2008).

However, ambient temperature and others climate is favorable within February to 1st week of March in Bangladesh, which is their main multiplication period under these prevailing condition. But, beginning to mid-march is not suitable for multiplication of aphid in Bangladesh due to rainfall because of adverse effects of rainfall on aphid multiplication. The negative relationship between aphid infestation and rainfall was remained in Bangladesh. In this time, aphid was washed out from plants. So, timely sown (1st and 2nd week of November) is the best option to avoid the more aphid incidence and damage due to unfavorable condition of weather (temperature (>25^{0}C) and climate (no rain and stream) for multiplication of aphid. On the contrary, maize crop was finished their life cycle (Vegetative, inflorescence and cob formation stage) properly.

5.4 Entomological features of maize aphid, *R. maidis* as affected by different sowing dates

Entomological features namely body length, number of maize aphid per plant without inflorescence and number of maize aphid per inflorescence was directly influenced by different sowing dates are shown in Table 6 and Figure 1.

5.4.1 Body length

Based on body length, in Table 06, from the result of the present study showed that, among different growth stages of maize, the highest (2.51mm) length of body of maize was recorded at the stage of cob formation which was followed by 2.32mm at the stage of vegetative, whereas, the lowest (2.10mm) length of body was found at the stage of inflorescence. Similar type of result was found by Wains et al., 2008. Besides, considering the body length of maize aphid on basis of different sowing dates, from the result of present study showed that the maximum (2.38mm) body length of aphid was obtained from S_6 followed by 2.37mm, 2.36mm, 2.34mm, 2.31mm, 2.30mm, 2.27mm and 2.27mm S_5, S_7, S_3, S_8, S_4, S_2 and S_9, respectively. The minimum (2.20mm) body length was observed from S_1 (sowing dates on 3rd week of October) (Table 6) (Sanp and Singh, 2018; Khinchi and Kumawat, 2014).

Table 6: Effect of different sowing dates on body length of maize aphid, Rhopalosiphum maidis

	Average body length (mm) of aphid, *R. maidis* in different sowing dates on									
Growth stages of maize	**S_1**	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	Average Body length (mm)
Vegetative	1.89	1.97	2.34	2.31	2.56	2.54	2.50	2.42	2.36	2.32
Inflorescence	2.08	2.20	2.15	2.10	2.06	2.12	2.10	2.09	2.08	2.10
Cob formation	2.63	2.65	2.53	2.51	2.50	2.49	2.48	2.44	2.39	2.51
Average Body length (mm)	2.20	2.27	2.34	2.30	2.37	2.38	2.36	2.31	2.27	

5.4.2 Number of aphid per plant without inflorescence

As the results showed, there were significant differences among the different dates of sowing on aphid incidence in plant at 5% level of probability (Figure 1). The highest (400) no. of aphid plant^{-1} without inflorescence was obtained from 4th week of November (S_6), which was followed by 365, 350, 330, 300, 280, 245 and 228 in S_7, S_5, S_8, S_4, S_3, S_9 and S_2, respectively. The lowest (200) no. of aphid plant^{-1} without inflorescence was recorded in S_1. The findings are supported by Maryam et al., 2011. They stated that, sown on mid-November had minimum number of aphid per plant effectively.

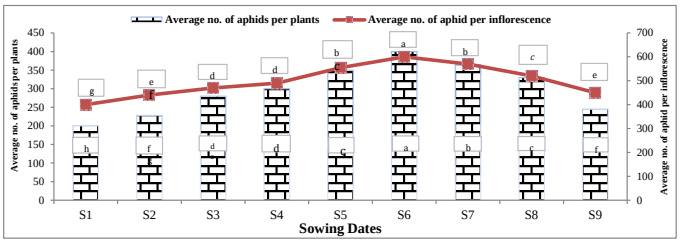

Figure 1: Effect of different dates on number of aphid per plant and inflorescence during 2016-17

5.4.3 Number of aphid per inflorescence

From the Figure 1, the results of this study showed that there were significant differences among the different sowing dates on aphid incidence in inflorescence (P≤0.05). The maximum (600) no. of aphid inflorescence^{-1} was observed sown dates on 4th week of November (S_6), which was followed by 570, 555, 520, 490, 470, 450 and 440 in S_7, S_5, S_8, S_4, S_3, S_9 and S_2, respectively. The minimum (400) no. of aphid inflorescence^{-1} was recorded in S_1 (Maryam et al., 2011). They stated that, sown on mid-November had minimum number of aphid per inflorescence effectively.

Over all the minimum body length and less number of aphids were recorded at inflorescence than vegetative and reproductive stage, which is why; less damage of pollen as well as produced higher yield, if seed sown on 1st week of November (Timely season). In this time, aphid can't damage plant and pollen of inflorescence. They are also unable to suck plant sap and unable to cause damage on pollen and fertilization. As a result, more yield is produced from this sown dates (Sanp and Singh, 2018; Khinchi and Kumawat, 2014).

5.5 Correlation between sowing dates and average mean percentage of aphid infested plant with grain world

The correlation co-efficient (r) of sowing dates with pooled data of aphid infested plants and yield revealed similar trend *viz.* 0.902 and -0.981, respectively. Thus, there was strongly significant (P≤0.01) positive correlation between sowing dates and aphid infested plants (Table 7), and on the other hand there was very strongly significant (P≤0.001) negative correlation between sowing dates and grain yield of maize crop during the experimental season in Bangladesh (Table 7). In case of sowing dates with aphid infested plants, the regression equation (Y_1=16.875+ 10.02×X_1) of sowing dates on aphid infested plants (%) showed the relationship between the dates of sowing as X_1 and aphid infested plants as Y_1, respectively, where the equation gave a good fit to the data and the co-efficient of determination (R^2=0.924**) fitted regression line had a significant regression co-efficient. It may be concluded from the Table 7 that if sowing dates early or late by one (01) week, the increase of average percentage of aphid infested plants by 10.02 percent.

That means sowing dates (early or late) was strongly positively correlated with the percent increase of aphid infested plants. On the other side, the different dates of sowing with grain yield, the regression equation (Y_2=7.38 – 0.654×X_2) of sowing dates on grain yield (t ha^{-1}) showed the relationship between the dates of sowing as X_2 and grain yield as Y_2, respectively, where the equation gave a good fit to the data and the co-efficient of determination (R^2=0.976***) fitted regression line had a significant regression co-efficient. It may be concluded from the Table 7 that if sowing dates early or late by one (01) week, the grain yield of maize causes decrease due to aphid infestation by 0.654 t ha^{-1}. That means sowing dates (early or late) was strongly negatively correlated decrease with the grain yield of maize due to aphid infestation. The equation showed the decreasing trend of the yield as sowing was delayed or early.

Table 7: Regression equation between sowing dates and aphid infestation with yield during 2016-17

Parameters	Correlation Coefficient (r)	Regression equation Y=a + bX	Coefficient of determination (R^2)
Sowing dates v/s Aphid infestation	0.902	Y_1=16.875+10.02×X_1	0.924**
Sowing dates v/s Grain yield	-0.981	Y_2=7.38- 0.654×X_2	0.976***

**means at 1% level of probability, ***means at 0.1% level of probability, X_1=X_2=Sowing dates, Y_1= Aphid infestation and Y_2= Grain yield

5.6 Correlation between percentage of infested plants and grain yield

Nine (09) different dates of sowing had significantly impact on maize production. They decrease grain yield of maize during production. But the impacts of nine sowing dates are not equal. Correlation study was done to establish the relationship between averaged percentage of infested plants and grain yield of maize. From the result of Table 8 it was revealed that very highly significant (P≤0.01) negative correlation was observed between the parameters. It was evident that the equation, Y_3= 12.44 – 0.0024×X_3, where Y_3=Grain yield (t ha^{-1}) of maize and X_3= average percent aphid infested plant of maize (%) gave a good fit to the data and the co-efficient of determination (R^2=0.961**) fitted regression line had a significant regression co-efficient. It may be concluded from Table 08 that if the average percentage of infested plants of maize affected by one (01) percent, the grain yield of maize causes decrease due to aphid infestation by 0.002 t ha^{-1}. That means the average percentage of infested maize plants was very strongly as well as negative correlated with the grain yield of maize during production. Grain yield of maize was decreased due to increase the percentage plant infestation of maize as affected by aphid, *R. maidis.*

Table 8: Regression equation between average percentage of infested maize plants and grain yield as affected by aphid, R. maidis during 2016-17

Parameters	Correlation Coefficient (r)	Regression equation Y=a + bX	Coefficient of determination (R^2)
Aphid infestation v/s Grain yield	-0.933	Y_3=12.44 – 0.0024×X_3	0.961**

**means at 1% level of probability, X_3= Aphid infested plant (%) and Y_3= Grain yield

6. Conclusion

It may be concluded from the finding of present research work that significant variations existed among the different dates of sowing. The sowing dates adversely affected on yield components which ultimately caused a significant decline in grain yield ha^{-1}. Among the different dates of sowing, minimum incidence of maize aphid was occurred sown on 1st week of November as sowing dates while maximum morpho-physiological characters and yield components & yield was also obtained with better quality. Based upon the present finding, we also found that, 2nd week of November was also considering the second best. Besides, considering to the different sowing dates, average aphid infested plants (%) and yield of maize, the present study showed that strongly significant positive correlation was found between sowing dates with aphid infested plants; very strongly significant negative correlation between sowing dates & grain yield of maize, and very highly significant negative correlation was observed between average infested plants (%) with grain yield of maize.

Henceforth, on the basis of body length, the minimum body length of aphid was recorded at inflorescence within different growth stages. On the others hand, in similar case, the tolerable body length was found sown on

1st week of November where maximum yield occurred than others parameters in both issues. However, considering the incidence of aphid, among different sowing dates, the minimum tolerable no. of aphid per plant and inflorescence was recorded sown on 1st week of November where the maximum grain yield occurred than others sowing dates. It is therefore, suggested that in order to minimize maize aphid infestation to tolerable level, body length, no. of aphid incidence per plant & inflorescence and produced higher yield, maize may be sown best in 1st week of November in Bangladesh, and 2nd week of November as sowing dates is the second best, where 1st week of November is not possible as sowing date due to maintains the cropping pattern.

Author's Contributions

Kazi Shaharana Ahmed and Md. Harun-or Rashid conceived, design, formulation and supervision of the experiments. Md. Jewel Alam performed the experiments, collected and analyzed the data. Mst. Khadija Khatun collected materials, tools and helped to set up the experiments. Most. Khairun Nahar collected information and helped to write the paper.

Conflict of Interest

The authors declare that they have no conflict of interest regarding the publication of this paper.

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