Preventing Fall Armyworm (*Spodoptera frugiperda* JE Smith) Damage in Maize by Altering Planting Time and Using Varied Genotypes

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Abstract

Fall armyworm (*Spodoptera frugiperda* JE Smith) is a polyphagous pest indigenous throughout the Americas which has invaded the African continent since 2016 from South America. It has had devastating effects on cereals with yield losses sometimes reaching 100%, and yet, there are no confirmed means of managing the pest. This militates against the achievement of sustainable development goal (SDG) number 2 which seeks to end hunger, achieve food security and improved nutrition and promote sustainable agriculture. It also impedes the achievement of SDGs 1 and 3 which, respectively, seek to end poverty and ensure good health and the wellbeing of all people, particularly people in resource-constrained societies. Thus, the experiments conducted in the study were aimed at determining the effect that maize genotypes and planting time had on fall armyworm (FAW) damage in a bid to minimise yield losses and concomitantly ensure food security. The results indicated that late planting resulted in a significant 40% increase in the incidence of FAW attack compared to early and medium planted maize crops. Consequently, early planting gave a significantly higher yield by 122% compared to late planting. In contrast, there were no significant effects of genotypes on the number of plants affected by FAW. The study concluded that early planting is effective in reducing FAW

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attack on maize and results in increased maize productivity in FAW endemic areas.

Keywords

Fall armyworm · Genotypes · *Spodoptera frugiperda* · *Zea mays* · Early planting

1 Introduction

Maize (*Zea mays* L.) is the single most important staple crop in sub-Saharan Africa (SSA) (FAO 2018). It constitutes about 75% or more of cereal area in countries like Kenya, Malawi, Zambia and Zimbabwe (Jayne 2003). Yet, maize as a vital source of food has been threatened by the invasive fall armyworm (FAW) that invaded the African continent since the year 2016.There are speculations that this pest might have come to Africa through imported or food aid consignments. Hruska (2019) reported that FAW has been a consistently important insect pest for a number of crop species especially maize in the United States. In the invaded range, FAW is projected to constitute a lasting threat to several important crops as the region provides diverse host sources and favourable climatic conditions for consistent reproduction in many areas (Midega et al. 2018).

FAW threatens to undermine the efforts to achieve sustainable development goals (SDGs) for millions of poor people in sub-Saharan Africa (SSA). The invasion of Africa by FAW is causing a serious threat to food security and adds to the insecurity caused by many other factors including extreme weather conditions such as the El Nino phenomenon and tropical cyclones. This in turn negatively impacts on the realisation of the second SDG which seeks to end hunger, achieve food security and improved nutrition and promote sustainable agriculture (United Nations 2015). Biotic constraints such as FAW have been reported to cause significant yield losses which affect food security among communities that rely on subsistence farming. In addition, the FAW scourge is a threat to SGD number 3 which seeks to double the agricultural productivity and increase the incomes of small-scale food producers, in particular women and resource-constrained smallholder farmers whose livelihoods solely depend on subsistence farming. The invasive nature of FAW also threatens the achievement of SDG 15 target number 8 which seeks to prevent the introduction and significantly reduce the impacts of invasive alien species on land and water ecosystems (United Nations 2015).

The potential economic impacts of FAW in Africa are huge. FAW has the potential to cause yield losses of 8.3 million to 20.6 million metric tonnes per year in just 12 of Africa's maize-producing countries in the absence of proper control methods (CABI 2017). The countries include the southern and eastern African countries such as Zimbabwe, Mozambique, Botswana, Zambia, Namibia, Swaziland, Malawi, Tanzania, Kenya and Uganda. The level of losses represents 21–53% of annual production of maize averaged over a 3-year period in these countries, and their value is estimated to be between US$2.48 billion and US$6.19 billion (CABI 2017). FAW could have serious regional and international trade through strict phytosanitary regulations which may reduce the movement of crop produce among different countries, particularly grain. Anecdotal evidence suggests that FAW has been intercepted at quarantine points in Africa and Europe, suggesting the potential for phytosanitary trade issues inside and outside Africa despite the pest being capable of migrating long distances on prevailing winds making natural migration a possibility (Huesing 2018). The polyphagous nature of FAW presents challenges in management due to the presence of numerous alternative hosts outside the production season of many crops (Hruska 2019).

2 Literature Review

2.1 FAW Distribution in Africa

FAW has been confirmed present in all the sub-Saharan African countries except Lesotho (Fig. 4.1). The environmental conditions in sub-Saharan African countries are suitable for the multiplication of the pest because the countries are in the tropical and sub-tropical regions (FAO 2019).

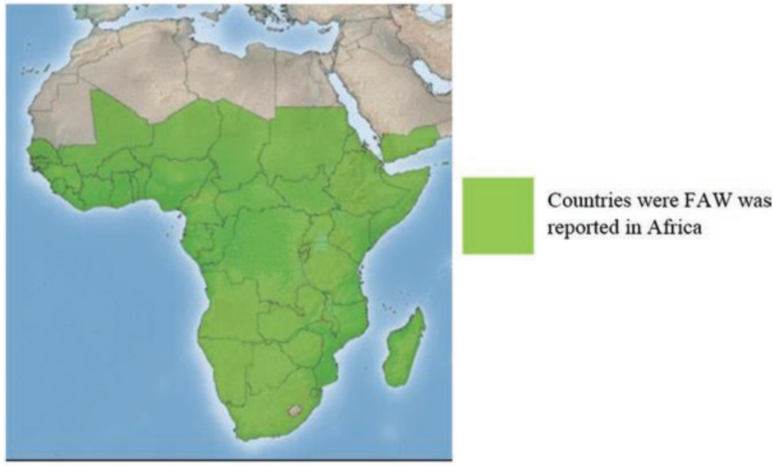


Fig. 4.1 FAW distribution in sub-Saharan Africa. (Source: FAO (2019))

2.2 Crop Losses

Damage by FAW is manifested through photosynthetic area loss, lodging, impaired reproduction and direct damage to grain (Chimweta et al. 2019). Young larvae mainly feed on epidermal leaf tissue and also make holes on the leaves, which is the typical damage symptom of FAW (Sisay et al. 2019). Given the importance of maize in Africa as a primary staple food crop, the recent invasion of FAW threatens the food security of millions of people in the sub-Saharan Africa region that will likely have an aggravated drought due to climate change or El Nino (Sisay et al. 2019).

2.3 Life Cycle

Following emergence, the adult moths feed on suitable flowers in the dark for up to 2 h, before females start their mating call by emitting pheromones that attract males to mate. Adults fly at night and are attracted to light, especially those with a strong ultraviolet component. The use of pheromone traps has been used to monitor populations in integrated pest management programmes (Cruz et al. 1999). Oviposition starts later on in the same night that mating takes place. Eggs are laid as 'egg masses' in batches of 100–200 eggs and hatch in 2–4 days in optimum temperatures (FAO 2019). Oviposition is usually on the underside of leaves, but as the density of moths increases, oviposition becomes increasingly indiscriminate on other parts of the host plant, other non-host plants and inanimate objects. Adult moths mostly live for 2–3 weeks. Females will mate multiple times during this period and lay multiple egg masses with a potential fecundity of up to 1000 eggs per female. There are six larval instars: it is the final instar which consumes the most plant material (77%) and causes the most damage. The developing larvae eat different parts of the host plant, depending on the crop, the stage of crop development and the age of the larvae. On maize, young larvae usually feed on leaves creating a characteristic windowing effect. This and moist sawdust-like frass near the funnel and upper leaves can be an easily spotted sign of larva feeding. The larvae also feed on the developing cob (Fig. 4.2).

2.4 Household Level

FAW is likely to directly affect capital costs through increased labour needed and the type of knowledge required to deal with the pest, through yield losses and the ability of agricultural lands to respond to shocks and, financially, through increasing the cost of production due to costs of control (defined as the cost of technology and its application) and its effect on income. It will also indirectly affect households' social and physical capital (the household's assets) (Harrison et al. 2019).

Fig. 4.2 *Spodoptera frugiperda* feeding on a developing maize cob. (Source: Authors)

2.5 Host Range

Field crops are frequently injured, including alfalfa, barley, Bermuda grass, buckwheat, cotton, clover, maize, oat, millet, peanut, rice, ryegrass, sorghum, sugar beet, Sudan grass, soybean, sugarcane, timothy, tobacco and wheat. Among vegetable crops, only sweet maize is regularly damaged, but others are attacked occasionally. Other crops which are sometimes injured are apple, grape, orange, papaya, peach, strawberry and a number of flowers. Weeds known to serve as hosts include bent grass, *Agrostis* ssp.; crabgrass, *Digitaria* spp.; Johnsongrass, *Sorghum halepense*; morning glory, *Ipomoea* spp.; nutsedge, *Cyperus* spp.; pigweed, *Amaranthus* spp.; and sandspur, *Cenchrus tribuloides* (Prasanna 2018).

2.6 Management of FAW in Zimbabwe

Crop losses due to FAW may be prevented or reduced by deploying effective crop protection measures which to a large extent depends on farmers' knowledge and behaviour towards pest management and the availability and effectiveness of crop protection methods (Kansiime et al. 2019). Elements of smallholder maize integrated pest management need to be carefully studied across ecosystems of Africa to better understand the conditions in which they work best and their mechanisms and to develop mechanisms that can be scale up (Abate et al. 2000; Hruska 2019). The sustainable approach is the integrated pest management approach which employs a multi-tactic approach to lower pest populations so that they go below economic injury levels which take into cognisance the economic status of the smallholder farmers (Mandumbu et al. 2011). Technically, these farmers have two ways of managing the pest: they can use either improved technology or traditional sustainable approaches which can be accommodated by their resources.

The ability of maize to compensate for foliar damage depends on genetics, nutrition and water availability of the plant. This therefore raises the need to test the currently available maize genotypes against FAW. This could provide the first line of defence to the maize crop and probably the cheapest way of managing the pest under smallholder agriculture. Many smallholder farmers grow maize under unsuitable conditions and as a result suffer yield losses due to inadequate nutrition and moisture stress. There is a need to develop sustainable FAW management techniques that fit into the economics of the smallholder maize producer for sub-Saharan Africa. Some farmers use sand, soap or unregistered chemicals. Most of these methods used by farmers and reasons underlying their use are anecdotal and lack scientific backing (Kansiime et al. 2019). The use of plant resistance and early planting are possible management methods that can be sustainable for resource-poor small-scale farmers. Early planting after effective rainfall usually provides better growing conditions for maize by making use of more heat units at the beginning of the cropping season. Early planted crops escape pest pressure as the crop life cycle will escape the time of pest abundance. According to Prasanna (2018), early planting creates asynchrony between the pest and critical crop stages. These options are especially key to SSA countries such as Zambia, Zimbabwe, Malawi and Mozambique where the majority of the farmers have limited access to safe and affordable FAW control options.

2.7 Cultural Pest Management

Cultural pest management strategy comprises of those methods that involve the manipulation of agrosystems in order to decrease the success of a pest species within it. Many cultural techniques form the basis of preventive pest management. From the arthropod pest management strategy, the primary aim of cultural management techniques are (i) to reduce the colonisation of a crop by a pest and to decrease the pest dispersal from that crop and (ii) to reduce the reproduction and survival of a pest in a crop once colonisation has occurred (Thacker 2002). Since the invasion of sub-Saharan Africa by the FAW, there has been a resurgence in the interest of cultural pest management strategies. However, private companies which are 'product' based do not have much interest in these strategies because of the absence of saleable products.

2.8 Planting Date Manipulation and Arthropod Pest Management

Many have periods during the year when they are most dispersive and can colonise plants more easily. For Zimbabwe, *Spodoptera frugiperda* does not appear in large numbers very early in the season probably because of the shortage of hosts from the dry summers. Planting date manipulation is therefore necessary to avoid the peak period for crop colonisation. Plants will therefore be able to establish themselves before pests arrive.

For Zimbabwe, early planting means the crop will get more heat units and therefore grow very fast compared to later planted crops. The early planted crop is likely to escape the periods of heavy infestation by *Spodoptera frugiperda*. This is a principle that was tested for other indigenous bollworms in cereals.

2.9 Effect of Maize Genotypes on the FAW Pandemic

The use of resistance is an attractive option particularly if the resistance is complete in the sense that the attacking organism is no longer able to cause economic damage. According to Thacker (2002), host plant resistance is a collective heritable characteristic by which plants may reduce the possibility of its utilisation as a host for the pest.

Sometimes, secondary plant substances are responsible for resistance. The main function of secondary plant metabolites is to act as a defence against herbivore attack by acting as repellents, inhibitors and toxins. Other compounds may deter feeding of pest, disrupt development, provide barriers from attack and assist with wound healing and to provide many other neurotoxins to herbivorous insects. Plants can also use a range of morphological features to defend against insect attack like the use of trichomes.

3 Materials and Methods

3.1 Description of Trial Location

The trial was conducted in Kandava village under Seke District in ward 4 in Mashonaland East Province which falls under Zimbabwe's Agro-ecological Region 2. The site coordinates are 18.1279° S and 31.2701° E. Site is 8 km from Marondera/Hwedza junction along Chitungwiza-Marondera road. Altitude is 1600 metres, and total annual rainfall ranges from 600 to 800 mm. Most of the rainfall is received from November to April.

3.2 Planting Preparations

Land preparation was done using an ox drawn plough. The maize varieties were planted in plots measuring 4 m × 5 m. Plant spacing was 0.75 m × 0.25 m, and distance between plots was 1 metre, while that between blocks was 3 metres. Two seeds were planted per station and thinned to one at 2 weeks after crop emergence (WACE) to leave a plant population of 53,333 plants per hectare. Compound D Fertilizer (7% N/14% P/7% K) was side dropped in planting stations at the rate of 350 kg ha^{-1}, and top dressing was split applied at 150 kg ha^{-1} at 4 and 8 WACE, giving a total of 300 kg ha^{-1} ammonium nitrate (34.5% N). The trial was under drip irrigation to safeguard against total crop failure due to drought. Irrigation was applied as a supplementary measure. Weeding was done three times at 3, 8 and 12 WACE using a hand hoe, and the site was kept weed-free at most times.

3.3 Monitoring and Observations Done

Although the trial was under rain-fed conditions, two survival irrigations were applied. A total of 20 mm was applied on each occasion using drip irrigation system.

Four mid-season maize hybrids were selected for evaluation. The selected hybrids are among the most commonly grown by villagers, and these were SC649, SC637, SC633 and DKC8053. The four maize hybrids were planted over three planting dates of 15 November, 15 December and 28 December signifying early, mid-season and late planting, respectively. FAW infestation was natural, and the site was previously grown to maize resembling the monoculture practises by the community which also ensured that sufficient infestation to the treatments occurred.

The trial was held under no chemical spray conditions for all treatments. The experimental design was a 4*3 factorial which was laid down in randomised complete block design (RCBD) giving 12 treatments replicated three times to give a total of 36 treatments. Blocking was done to reduce the effect of environmental factors such as soil texture and slope.

A plant was randomly selected to be the 1st of five consecutive plants in each treatment as from 2 WACE for leaf score measurements. The first row was omitted for edge effect, and sampling was done from the second row of each plot. The first metre on the sampling row was also omitted for the same reason. Each of the five consecutive plants was examined to determine the number of damaged leaves and leaf lesion size. Records of foliar damage ratings were done using a nine 9-point visual rating scale (1, no damage, to 9, severe foliar damage) (Davis and Williams 1992) (Table 4.1). A score was given for each plant, and an average was recorded for the treatment.

The number of affected plants was also recorded at each sampling for particular growth stages and on the same plants sampled for leaf damage score. Whole plot counts were done to determine the number of plants affected by FAW. The number affected for each treatment was expressed as a percentage of the total. One hundred plants were sampled per each treatment to determine exit holes. Fifty plants were sampled per treatment to determine kernel score at maturity stage, and whole plots were harvested and cobs sun dried to 12% moisture to determine yield. Yield per plot was adjusted per hectare basis. Discard as a result of FAW damage and subsequent secondary infection of grain was also recorded following harvesting.

3.4 Data Collection and Analysis

Data collected were leaf damage score as explained above, exit holes, kernel score (modified Davies scale), Yield (t ha^{-1}), and percent discard yield (t ha^{-1}) as a result of FAW damage. The data were subjected to analysis of variance

Table 4.1 Scale for assessment of foliar damage due to FAW in maize germplasm entries. Score damage symptoms/description response

Scale	Description	Resistant/ susceptible
1	No visible leaf-feeding damage	Highly resistant
2	Few pinholes on 1–2 older leaves – resistant	
3	Several shot-hole injuries on a few leaves (<5 leaves) and small circular hole damage to leaves	Resistant
4	Several shot-hole injuries on several leaves (6–8 leaves) or small lesions/pinholes, small circular lesions and a few small elongated (rectangular-shaped) lesions of up to 1.3 cm in length present on whorl and furl leaves	Partially resistant
5	Elongated lesions (>2.5 cm long) on 8–10 leaves, plus a few small- to mid-sized uniform to irregular-shaped holes (basement membrane consumed) eaten from the whorl and/or furl leaves	Partially resistant
6	Several large elongated lesions present on several whorl and furl leaves and/or several large uniform to irregular-shaped holes eaten from furl and whorl leaves	Susceptible
7	Many elongated lesions of all sizes present on several whorl and furl leaves plus several large uniform to irregular-shaped holes eaten from the whorl and furl leaves	Susceptible
8	Many elongated lesions of all sizes present on most whorl and furl leaves plus many mid- to large-sized uniform to irregular-shaped holes eaten from the whorl and furl leaves	Highly susceptible
9	Whorl and furl leaves almost totally destroyed and plant dying as a result of extensive foliar damage	Highly susceptible

Source: Modified from Davis and Williams (1992)

using Genstat version14 after testing for normality and other assumptions of analysis of variance. Where there were significant differences the means were separated using the least significant differences at 0.05 probability level.

4 Presentation and Discussion of Findings

Leaf average score, number of maize plants infested, average exit holes, kernel average score and yield were not significantly ($p > 0.05$) affected by maize genotype (Table 4.2).

Maize genotypes did not show any significant differences on FAW damage across all the growth stages. This could be because the maize hybrids used could have emanated from similar or related parental lines. It is important to note that three of the maize varieties used emanated from the same seed producing company and the possibility of them emanating from the same or related parents are high. The results concur with findings by Harrison et al. (2019) who articulate that there are a few corn varieties which can withstand earworm or FAW attack.

The results indicated that FAW has no oviposition and feeding preferences among the genotypes used which means that the pest is likely a generalist pest. Goergen (2016) also reported that breeding for FAW resistance has only been initiated in Africa, and therefore, there are no current varieties which can withstand FAW attack. Prasanna (2018) also confirmed that Africa has no adapted varieties with scientifically validated resistance to FAW. This gap is however being currently addressed by the International Maize and Wheat Improvement centre (CIMMYT) who is evaluating several germplasm for resistance to FAW (Prasanna 2018). Again, in other seed companies which are privately owned, breeding has been initiated as it might provide a sustainable management of the pest in the face of impoverished African farmers who do not afford chemicals and associated application devices.

Therefore, to date, there are no confirmed maize varieties that can withstand the effects of FAW which signifies the absence of antixenosis, tolerance, antibiosis and apparent resistance in the tested genotypes. Given that volatiles from plants differ quantitatively and qualitatively, FAW moth and lar-

Table 4.2 Effect of variety on LAS, number affected, AEH, KAS and maize yield

Variety	Leaf average score	Maize plants affected	Average exit holes	Kernel average score	Yield (t ha^{-1})
SC627	1.93	49.5	0.28	3.33	2.57
SC639	1.99	56.3	0.358	2.93	2.76
SC633	2.02	48.9	0.56	3.44	2.65
DKC8053	2.16	59.9	0.527	3.15	2.8
P-value	>0.05	>0.05	>0.05	>0.05	>0.05
Sed	NS	NS	NS	NS	NS

vae are presented with differences in olfactory cues when making choices among hosts (Carroll et al. 2006). Varieties would differ in the quality and quantity of volatiles and that may influence the oviposition behaviour of the moth and the feeding behaviour of the larvae in different sorghum varieties. However, it was not the case in this study as the varieties were uniform in influencing FAW moth oviposition. Efforts are currently under way in the international research organisations such as CIMMYT and the International Institute of Tropical Agriculture where they are evaluating a lot of germplasm for determination of resistance. It is hoped that the African breeding community may take a coordinated approach to develop elite varieties with relevant traits for smallholder farmers in Africa. It also has to be noted that breeding is a continuous process with no finishing line to the perpetual race between the host and the evolving pest.

4.1 Effect of Time of Planting on Maize Damage by FAW

Time of planting had a significant ($p < 0.05$) effect on maize damage by FAW. Late planting had the highest score of 3.3, while early planting and mid-season planting were the same with means of 2.57 and 2.53, respectively (Fig. 4.3).

4.2 Effect of Time of Planting on Leaf Damage

Time of planting significantly affected the number of maize damages by FAW as measured by the Davies scale (Fig. 4.4). The results show that the late the planting, the more the damage to a maize crop across all varieties. Time of planting has for long been recognised as a cultural management technique for smallholder farmers in traditional agriculture.

4.3 Effect of Time of Planting on Number of Plants Damaged at Reproductive Stage

Time of planting had a significant ($p < 0.05$) effect on number of maize plants damaged at reproductive stage. Early planting had significantly lower numbers of plants affected with a mean of 21%. On the other hand, late planted maize had significantly higher numbers of damaged plants with a mean of 83.4% compared to mid-season planted maize which had a mean of 56.5% (Fig. 4.5).

Visual leaf score damages showed that the late planted crop was severely damaged by FAW compared to late planted crop (Plates 4.1 and 4.2).

4.4 Effect of Time of Planting on Maize Yield

Variety had no significant ($p < 0.05$) effect on maize yield. However, time of planting significantly ($p < 0.05$) affected yield of maize. Early planting had the highest yield of 3.93 t ha^{-1}, while late planting had the lowest yield of 1.77 t ha^{-1}. Yield for mid-season planting was 2.39 t ha^{-1}. Late and mid-season planting performed the same in terms of yield (Fig. 4.6).

Fig. 4.3 Effect of time of planting on FAW attack. (Source: Authors)

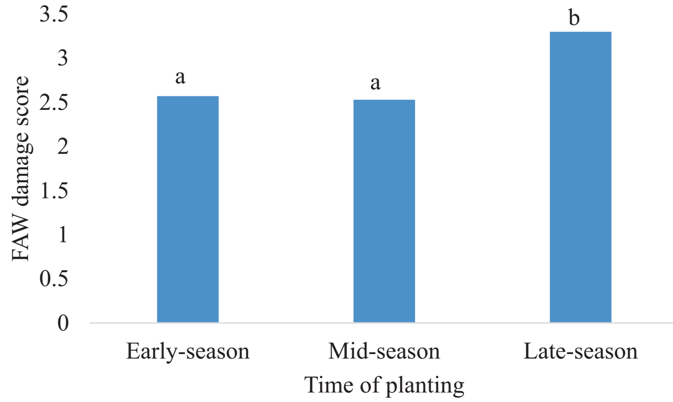


Fig. 4.4 Effect of time of planting on leaf damage (Davies scale). (Source: Authors)

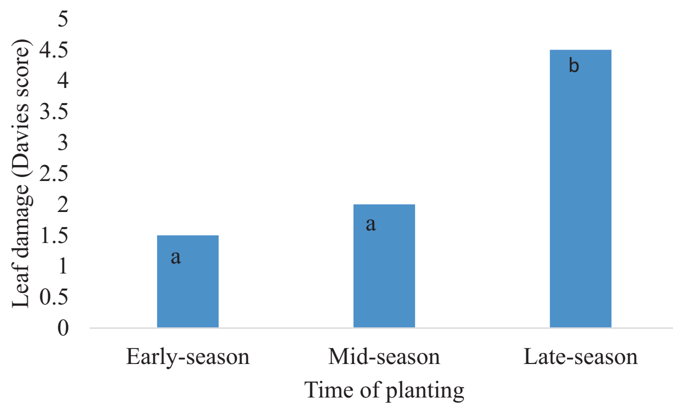


Fig. 4.5 Percent number of plants affected by FAW at reproductive stage. (Source: Authors)

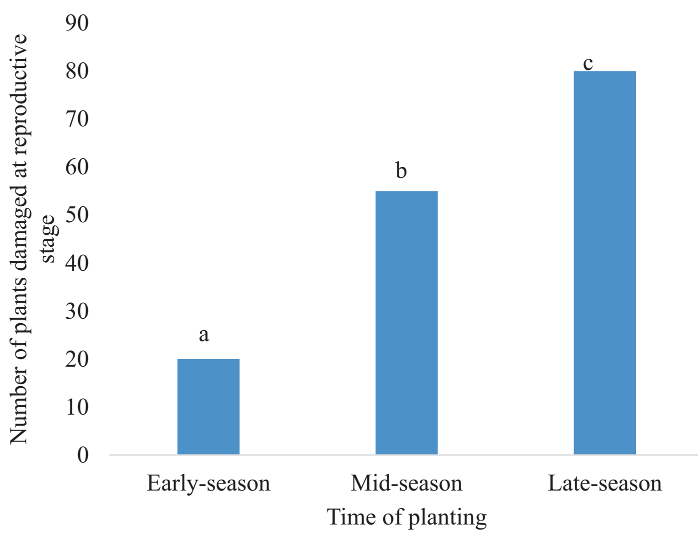
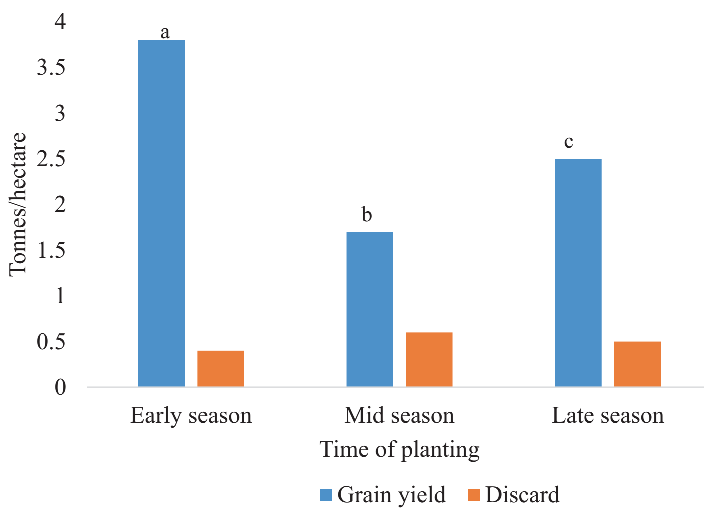


Plate 4.1 FAW damage on late planted crop

Plate 4.2 FAW damage on early planted crop

Fig. 4.6 Effect of the time of planting on maize yield (t ha^{-1})



4.5 Relationship Between Maize Yield and Time of Planting

Maize yield was significantly ($p < 0.05$) affected by the day of planting from the first rains (Fig. 4.7). The results show that the earlier the planting, the higher the yield. There was a strong positive correlation coefficient ($R^2 = 0.99$) between the day of planting and yield which shows a strong relationship between the day of planting and yield.

4.6 Relationship Between Day of Time of Planting and Percent Maize Discard

There was a significant ($p < 0.05$) effect of time of planting on the discarded grain at the shelling stage (Fig. 4.8). The percentage of discarded grain grew with increase from the day of the first rains. A correlation coefficient of 0.961 showed a very strong relationship between the two.

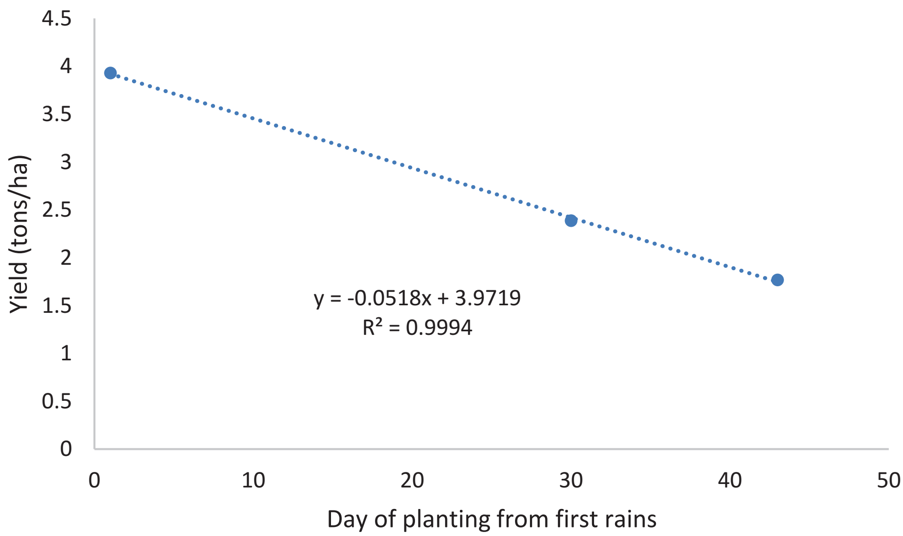


Fig. 4.7 The relationship between maize yield and time of planting. (Source: Authors)

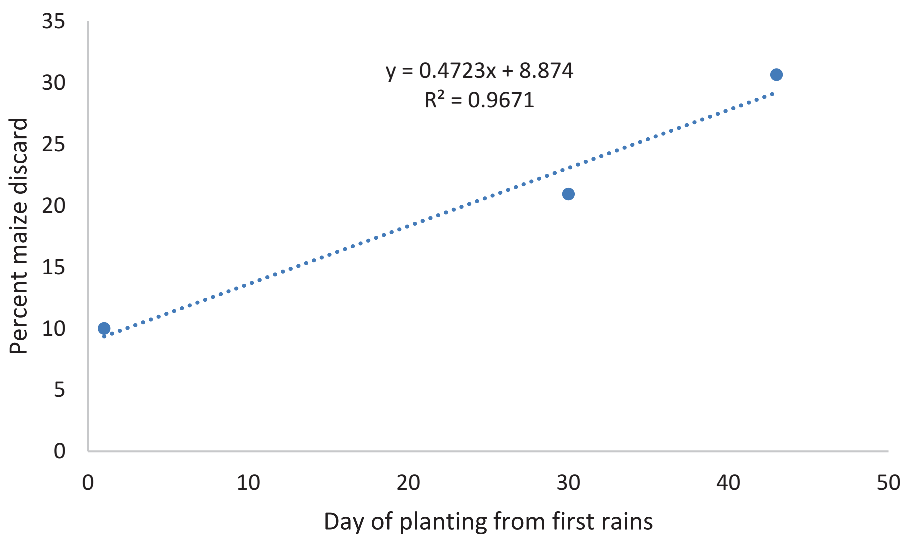


Fig. 4.8 The relationship between time of planting and percent maize discard. (Source: Authors)

5 Relationship Between Time of Planting and Leaf Average Score

Leaf average score and day of planting from the day of the first rains had a correlation coefficient of $R^2 = 0.662$ which showed a close relationship between the two. The results showed that leaf damage score increased with days of planting from the first rains (Fig. 4.9).

There was, however, no significant difference between mid-season planting and late season planting on kernel score. There was a significant difference between late and early planting (Fig. 4.10). Early planting had the least score of 1.22. Mid-season planting had the highest score of 4.38. Early planting was different from the rest, while mid- and late planting were ranked the same.

The following plate shows results in picture form for observed parameters (Plates 4.3, 4.4, 4.5, and 4.6). The results show that late planting

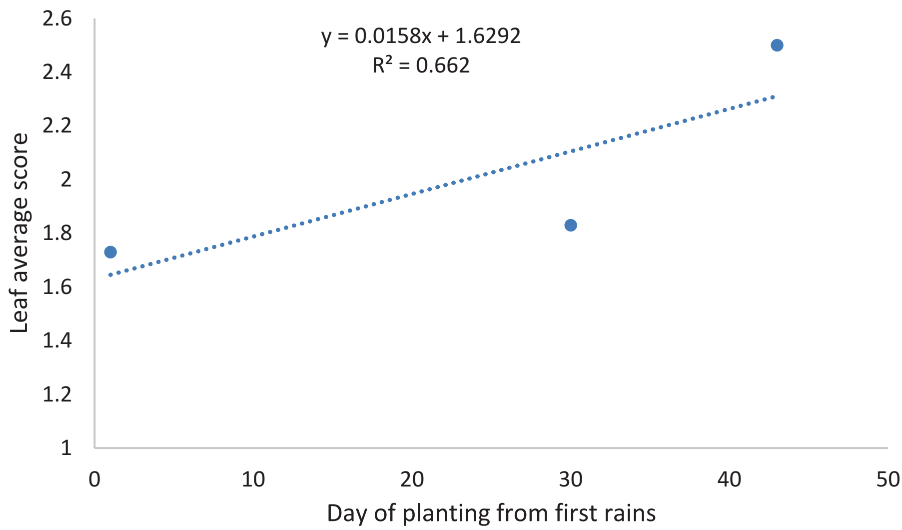
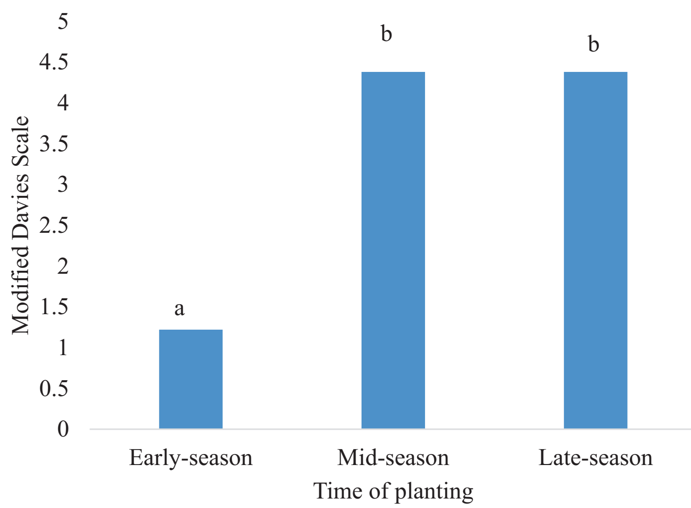


Fig. 4.9 The relationship between leaf average score damage and day of planting from first rains. (Source: Authors)

Fig. 4.10 Average kernel score (modified Davies scale)



results in serious damage to grain cobs by FAW, a phenomenon that is avoided by early planting.

Early planting led to significantly less percentage of plants being affected by FAW. According to Harrison et al. (2019), early planting is done to avoid peak migration of the FAW adult moth. According to Gebre-Amlak et al. (1989), early planting has worked for other stem borers because when planted early, crops have higher chances of escaping pest infestation compared to late planting. Mitchell et al. (1991) also noted that early planting is the most important cultural practice employed widely in the southern states of the United States to avoid the pest and early maturing varieties to mitigate against FAW. Recently CABI (2017) recommended early planting to escape FAW attack.

Midega et al. (2018) also noted that early planting after the first effective rainfall usually

Plate 4.3 Effect of FAW attack on kernel damage on late planting (damaged grain) compared to early planting (undamaged grain) for DKC8051

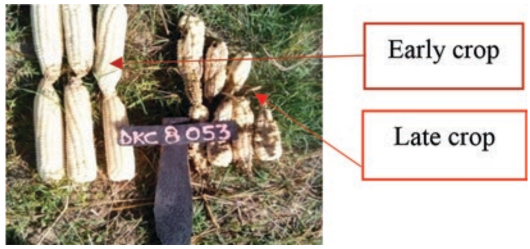


Plate 4.4 Late crop (left) and early crop (right)

Plate 4.5 Early crop (left) and late crop (right) for SC 633)

provides better growing conditions for maize making better use of more heat units at the beginning of the growing season. The resultant healthy plants may be capable under good moisture and nutrition conditions to compensate for foliar damage that may appear alarming to farmers (Abate et al. 2000). However, many smallholder farmers grow maize under unsuitable conditions and hence suffer greater losses due to poor nutrition and moisture stress (Hruska 2019).

Maize yields decreased with delay in time of planting from the first rains. Generally, early planted crops receive better heat units and generally grow faster than later planted crops. However, the main reason for differences between the pictures shown was because of FAW infestations. For similar varieties, there were striking differences between early planted and late planted maize. Hruska (2019) reported that late planting is often infested with high levels of FAW as

Plate 4.6 Late crop (left) and early crop (right) for SC 637. (Source: Authors)

moths increase as the season progresses and seek vegetative maize. Cobbing of late planted maize coincides with peak FAW period, and hence, grain damage increased. Soft dough stage cobs are more preferred as they are softer, and that results in substantial grain damage resulting in a higher percentage in discard.

As can be noted from plates 3, 4, 5, 6 and 7, the damage done to the crop due to late planting was extensive. The late crop coincided with the peak pest stages, and that could have resulted in extensive infestations with subsequent serious yield losses as was indicated on the yield. Therefore, manipulating host plant development through altering planting dates relative to the pest creates asynchrony between the pest and the critical crop stages (Thacker 2002).

6 Conclusion and Future Implications

The study concludes that the maize genotypes used did not contain any form of partial or complete resistance to FAW. Although new breeding was initiated across all the breeding houses in Zimbabwe and the regions so far no genotypes was found to be resistant to the pest. However, the results from this study also showed the effectiveness of early planting as a means of managing the pest. Early planting was shown to reduce the number of plants affected by FAW per plot. The cob quality tended to be lower the later the maize plantings. Evidence from other agronomic management practices for other stem borers showed that these agronomic techniques which are relatively affordable and friendlier to the environment are good for adoption. There is a need for promoting these low-cost methods for FAW management. This may form the basis for developing an integrated pest management programme which seeks to use all the suitable techniques in a compatible manner to maintain population levels below the economic injury level. Early planting affects the larvae whose effect tends to lessen as the time of infestation relative to the age of the plant delays. The sensitivity of the crop to FAW tends to get reduced with delay on the time of infestation. Further studies need to be conducted to test the effects of other agronomic techniques such as irrigation planting density, manuring, fertiliser application, crop rotation and clean cultivation on the FAW pandemic.

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