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Effect of Delayed Harvesting on Maize Ear Rot in Western Kenya

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Abstract: Maize ear rot is an important disease in Kenya. Despite causing yield losses the ear rot fungi also contaminate infected grains with mycotoxins. In western Kenya, the leading maize producing region of the country, farmers habitually leave their maize in the field upon maturity so as it may dry, but the harvest season often coincides with the second rains and the result is often increased rotting. Using on farm experiments in farmers' fields with 12 farmers at both Malava and Tongaren in Westen Kenya. Ten varieties were planted and harvested at 4, 8 and 12 week harvest time points after physiological maturity. Four farmers from every region were randomly selected at each harvest time point and their crop harvested. Relevant data that included percentage rotten grain, ear rot incidence, severity, borer incidence, lodging and drooping of ears was collected. The results showed that delayed harvesting increases ear rotting. Many ear rot resistance traits like closed ear tips, hard to lodge stems, drooping ears and resistance to insects were compromised when maize was left in the farm for longer periods of time. Farmers are therefore advised to harvest their maize at four weeks after physiological maturity to avoid further rotting and possible lethal contamination of grains by mycotoxins.

Key words: Ear rot fungi · Harvest interval · Predisposition · Western Kenya · Maize · Physiological maturity

INTRODUCTION

Demand for maize grain is projected to increase by 50% globally by 2020, including 93% in sub-Saharan Africa, 92% in South Asia, 62% in Latin America and 46% in East and Southeast Asia [1]. It is therefore alarming that despite the existing shortfall in maize demand diseases still rank highly as a maize production constraint [2]. Among the diseases at least as attested by the considerable research carried out on them, ear rot have not received the attention they disserve [3]. Other than ear rots causing yield losses through rotting, they also reduce the grain quality by producing mycotoxins which have been shown to pose human and animal heath risks and carcinomas [4-6]. Hence, researchers can no longer afford to overlook the ear rots. The major ear rot pathogens belong to fungi of the genera *Fusarium,* S*tenocarpella, Aspergillus, Penicillium* Nigrospora and *Macrospora* [7].

Symptoms of ear rot fungi in maize include Pinkish, red-brown or grey if badly rotten for fusarium ear rots, where as light brown kernels scattered on cob and light weight kernels is associated with S*ternocarpella* ear rots. *Asperillus* ear rots occur as green and black moulds [8-10]. *Fusarium verticillioides* can occur on maize symptolesssly [2]. In Kenya, farmers tend to leave maize in the field beyond physiological maturity to allow for further drying, but often delayed harvesting coincides with the second rains resulting in increase d ear rotting. At present, information on the full extend of delayed harvesting on maize ear rot in the different maize varieties in Kenya is not well documented. This study attempted to elucidate the effect of different harvest time points (HTPs) after physiological maturity on maize ear rot fungi in the leading maize producing region in Kenya. Because of the biased nature of on station research we opted for farmers fields for the experiments.

MATERIALS AND METHODS

This study was conducted in 2002 during the long rains. Twenty four farmers equally distributed between Malava and Tongaren locations in Western Kenya were used. Twelve farmers were randomly selected from each of the two divisions based on factors that included availability of land for 10 varieties, willingness to participate in the project and farm accessibility. Every farmer grew maize varieties H614, H622, H625, H626, H627,

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H628, H513, KSTP' 94, Pioneer 3253 and Namba nane. The varieties have different susceptibilities to ear rot fungi and have relatively similar maturity periods.

Each plot where a variety was planted comprised of 12 rows with 17 plants in each row. The inner 10 rows were harvested and used for data collection. The row on each side of the plot served as a border row. Four farms were randomly selected from the pool and harvested at 4, 8 and 12 weeks HTPs after physiological maturity in each division. Information on ear placement heights, lodging, ear rot, borer incidence, open ear tips and drooping ears at all stages of harvest were recorded. Ear rot severity was evaluated using a seven-class rating scale by Harris *et al*. [11]. The data was subjected to Analysis of Variance using Genstat Statistical Programme.

RESULTS

In Tongaren, percentage rotten grain was significantly (P=0.05) different between the three harvesting intervals and also significant (P=0.05) between varieties. Between 4th and 12th week HTP, significant (P=0.05) differences in percentage rotten grain were recorded in all varieties except H628 (Table 1). Significant (P=0.05) differences in percentage rotten grain were also observed in the different varieties at all HTPs. Between 4th and 12th HTPs the highest percentage rot was 40.3% in variety H622 at 12th week HTP and was significantly different from all the other varieties except variety H614, H622, H625, H627 and H628 at 8th week HTP and H614, H625, H627 and KSTP' 94 at 12th week HTP. The lowest percentage recorded was 9% in variety KSTP'94 at 4th week HTP and this was significantly (P=0.05) different from all varieties except PHB3253 and H513 at 4th week HTPs. Average percentage rot in ten varieties was 17% 27% and 31% for 4th, 8th and 12th week HTP respectively (Table 1).

Percentage rotten grain in Malava was significantly (P=0.05) different between varieties and also between HTPs. The highest percentage rot was 42% in variety H627 at the 12th week HTP. This differed with all varieties at all HTPs except H628 and H625 at 12th week HTP, KSTP' 94, H628 H627 and H622 at 8th week HTP and H628 and H627 at 4th HTP. The lowest percentage rotten grain in Malava was 10% in No. 8 at the 4th week HTP and was significantly (P=0.05) different from all varieties except PHB3253, H614 and H513 at 4th week HTP. The overall mean percentage rot for 4th, 8th and 12th week HTPs in Malava was 19.0, 24.0 and 28.0%, respectively (Table 1).

There was significant (P=0.05) difference in disease severity in Tongaren in varieties and also between HTPs. The highest disease severity (71%) was observed in variety H627 at the 12th week HTP and was significantly different from all varieties except H628 at 12th week HTP. The lowest ear rot severity was 29% in variety No. 8 at 4th week HTPand was significantly (P=0.05) different from all varieties except H513, PHB3253 and H622 at 4th week HTP. The ear rot mean severity increased with time for the three HTPs and was 47%, 54% and 62% at 4th, 8th and 12th week HTP respectively (Table 2).

Table 1: Percentage rotten gain in ten varieties at three harvest time points in Tongaren and Malava divisions

	[2]Percentage of total maize yield rotten					
	Tongaren division[1]			Malava division[1]		
Variety	4 weeks	8 weeks	12 weeks	4 weeks	8 weeks	12 weeks
H513	12.0ab	19.0defg	20.0defg	12.0ab	18.0def	23.0fgh
H614	18.0cde	34.0ijkl	33.0ijkl	27.0hijk	25.0ghij	17.0cde
H622	15.0bcd	26.0l	40.3l	18.0def	31.0jk	22.0efgh
H625	17.0bcde	26.0l	35.0l	25.0ghij	25.0ghij	34.0ijk
H626	22.0efghi	38.0hij	28.0hij	17.0hij	19.0defg	21.0efgh
H627	25.0fghi	37.0l	38.0l	30.0ijk	28.0hijk	40.0k
H628	30.0hij	27.okl	37.0l	32.0ijk	28.0hijk	40.0k
KSTP'94	9.0a	25.0efgh	22.0efghi	16.0bcd	22.0efgh	24.0fghi
No. 8	14.0bcd	20.0def	20.0def	10.0a	21.0efgh	21.0efgh
PHB3253	14.0bcd	21.0ijk	32.0ijk	13.0abc	15.0bcd	18.0def
Interval average	17.0bcde	27.0l	31.0ijk	19.0def	24.0fghi	28.0hijk

[1]Site data was separately analyzed

[2]Numbers in the table are means of four replicates and are significantly different (P=0.05) if followed by different letters and are from same site

Table 2: Ear rot severity in ten varieties at three harvest time points in Tongaren and Malava divisions

	[2]Ear rot severity (% rotten grain per cob)					
	Tongaren division[1]			Malava division[1]		
Variety	4 weeks	8 weeks	12 weeks	4 weeks	8 weeks	12 weeks
H513	31.0ab	45.0cdef	42.0abcd	46.0cd	55.0efghi	57.0fghij
H614	45.0cdef	50.0cdefg	50.0cdefg	38.0ab	55.0efghi	65.0klm
H622	42.0abcd	51.0cdefgh	61.0fghi	59.0ghijk	60.0hijk	65.0klm
H625	39.0abc	39.0abc	53.0defgh	52.0cdefg	58.0ghijk	58.0ghijk
H626	57.0fgh	51.0cdefgh	56.0efgh	50.0cdef	55.0efghi	63.0jkl
H627	48.0cdef	49.0defg	71.0i	32.0a	53.0defgh	75.0n
H628	53.0defgh	54.0defgh	69.0hi	58.0ghijk	60.0hijk	63.0jkl
KSTP'94	44.0cde	51.0cdefgh	55.0efgh	71.0mn	46.0cd	60.0hijk
No. 8	29.0a	49.0cdefg	54.0defgh	49.0cde	45.0bc	60.0hijk
PHB3253	39.0abc	51.0cdefgh	55.0efgh	45.0bc	55.0efghi	70.0hijk
Interval average	47.0cdef	54.0defgh	62.0ghi	50.0cdef	54.0efghi	61.0ijk

Table 3: Ear rot incidence in ten varieties at three harvest time points in Tongaren and Malava divisions

	[2]Ear rot incidence					
	Tongaren division[1]			Malava division[1]		
Variety	4 weeks	8 weeks	12 weeks	4 weeks	8 weeks	12 weeks
H513	9.0a	20.0ef	26.0hij	12.0a	13.0ab	15.0ab
H614	21.0efg	35.0nop	37.0nopq	20.0efg	28.0hijk	28.0cde
H622	15.0bcd	31.0klmn	45.0t	22.0efgh	26.0hijk	29.0hij
H625	18.0cde	29.0ijkl	34.0mn	19.0efg	25.0hijk	27.0hij
H626	20.0ef	40.0qrs	42.0rst	20.0jkl	24.0hijk	26.0hij
H627	27.0hijk	28.0ijk	42.0rst	29.0ijk	32.0ghij	35.0l
H628	35.0nop	33.0lmn	44.0st	31.0kl	32.0kl	35..0l
KSTP'94	12.0ab	23.0fgh	29.0ijkl	16.0bcd	18.0def	28.0hijk
No. 8	15.0bcd	21.0efg	25.0gh	14.0abc	18.0def	19.0def
PHB3253	21.0efg	21.0efg	30.0jklm	13.0ab	13.0ab	20.0efg
Interval average	19.0def	28.0ijk	39.0pqr	20.0efg	23.0efg	26.0fghi

[1]Site data was separately analyzed

[2]Numbers in the table are means of four replicates and are significantly different (P=0.05) if followed by different letters and are from same site

Ear rot severity in Malava was not significantly (P=0.05) different between the different HTPs and also between the different varieties (Table 2). The HTP ear rot severity average was 50%, 54% and 61% at 4th, 8th and 12th week HTP respectively. The average ear rot disease severity for 4th week HTP was 50% and was only significantly (P=0.05) different from 12th week HTP mean severity and not mean severity for 8th week HTP. However, there was a trend towards increasing ear rot severity at late HTP (Table 2).

Significant (P=0.05) differences were recorded in ear rot incidence in Tongaren between varieties and also between HTPs. No significant (P=0.05) differences were observed between HTPs and varieties, except for variety PHB3253. The highest ear rot disease incidence was 45 % in variety H622 at 12th week HTP whereas the lowest (9.0 %) was in variety H513 at 4th week HTPs (Table 3). Average ear rot disease incidence at the three HTPs was 19%, 28% and 39% for 4th, 8th and 12th week HTP respectively and was significantly (P=0.05) different (Table 3).

Table 4: Numbers of lodged plants at three harvest time points in Tongaren and Malava divisions

	[1]Number of lodged plants from 170					
	Tongaren division[2]			Malava division[2]		
Variety	4 weeks	8 weeks	12 weeks	4 weeks	8 weeks	12 weeks
H513	10.0ab	12.0bc	41.0fg	41.4a	45.0ab	65.0efghi
H614	25.0ef	34.0cde	45.0gh	53.0bcd	59.0cdef	75.0ijk
H622	26.0ef	26def	89.0j	64.0efgh	75.0ijk	94.0l
H625	15.0fg	35.0gh	69.0hij	62.0defg	61.0cdefg	72.0hij
H626	26.0ef	27.0def	42.0fgh	60.0defg	63.0cdefg	59..0cdef
H627	23.0gh	46.0gh	60.0hi	73.0ijk	78.0jk	78.0k
H628	38.0fgh	41.0fg	74.0ij	62.0fghi	68.0defg	80.0k
KSTP'94	34.0fg	46.0fg	69.0hij	48.0ab	58.0cde	75.01ijk
No. 8	25.0cde	35.0gh	48.0gh	52.0bc	60.0cdefg	69.0ghij
PHB3253	6.0a	28.0cde	47.0gh	53.0bcd	55.0bcd	76.0ijk
Interval average	23.0h	33.0fg	57.8hi	59.0cdef	60.0cdefg	75.0ijk

[1]Numbers in the table are means of four replicates.

[2]Site data was separately analyzed and is significantly different (P=0.05) if followed by different letters and are from same site

Malavas' ear rot disease incidence was only significantly (P=0.05) different between the varieties and not between HTPs. Varieties H627 and H628 had the highest ear rot incidences of 35% at the 8th and 12th week HTPs and this was significantly (P=0.05) different from all varieties, except for H622 at 12th week HTP. The variety H614 had the lowest ear rot disease incidence of 12% at the 4th week HTP. Ear rot incidence was significantly different (P=0.05) between 4th and 12th week HTP in all varieties, except for H627, H628, KSTP'94 and No. 8. However, the HTP means were not significantly (P=0.05) different from each other. The average ear rot disease incidences for 4th, 8th and 12th week HTPs were 20, 23 and 26%, respectively (Table 3).

Percentage of lodged maize plants was significantly different between varieties and also between HTPs in Tonageren division. The highest percentage lodging was 89% in variety H622 at 12th week HTP and was significantly (P=0.05) different from other varieties except for KSTP'94 and H628 at the 12th week HTP. Generally there was a trend towards increased lodging with time after 4th week HTPs. For Malava percentage lodged maize plants were significantly (P=0.05) different between varieties and also between HTPs. Between 4th and 8th week HTPs significant (P=0.05) differences were revealed between varieties H622, H627 and KSTP' 94. Between 4th and 12th week HTPs, significant (P=0.05) differences were recorded between all varieties except variety H627 and H626. The HTPs averages were significantly (P=0.05) different and were 59%, 60% and 75% for 4th, 8th and 12th week HTPs respectively. Variety H622 recorded the highest lodging percentage of 94 % at the 12th week HTP where as H513 recorded the lowest lodging percentage of 41% at the 4th week HTPs (Table 4).

Number of drooped ears were not significantly (P=0.05) different between varieties but were significantly (P=0.05) different between HTPs in Tongaren. The variety KSTP' 94 recorded high drooped ear numbers than all the other varieties at the 4th week HTPs. The highest number of dropped ears was 158 ears in variety H626 at 12th week HTP. There was more dropping of ears as maize delayed in the field. There was significant (P=0.05) difference in number of bare tips in both variety and HTP. The highest number was 12 ears and was recorded in H627. Ear placement heights in Tongaren were significantly (P=0.05) different between varieties with the highest placement in H628 at 198 inches from the ground. Borer incidence was significantly (P=0.05) different between varieties and also between HTPs with the highest borer incidence of 49 % recorded in variety H628 (Table 5). Correlation analysis between ear rot incidences and borer damage was found to be positive r = + 0.62.

Number of dropped ears in Malava division were significantly (P=0.05) different at the three time intervals with PHB3253 recording the highest number of 123 dropped ears out 170 this was significantly (P=0.05) different from all varieties (Table 6). Ear placement heights were also significantly (P=0.05) different between varieties with H627 and H628 recording the highest placement heights of 162 inches and 168 inches respectively.

Table 5: Performances of ten varieties in Tongaren division

	[1]Mean value for the trait					
Variety	[2]Ear height (inches)	[2]Openear tips	[2]Ear rot severity %	[2]Rot incidence %	[2]Borer incidence %	[2]Dropped ears
H513	138.0b	9.0c	32.0a	18.1a	34.0ab	113.0a
H614	188.0d	5.0bc	48.0f	31.3bc	45.0cd	133.0cd
H622	148.0c	4.0ab	44.0d	30.70bc	34.0ab	119.0b
H625	184.0d	2.0a	36.0b	27.3b	44.0cd	126.0b
H626	188.0d	3.0ab	49.0g	31..3bc	44.0cd	128.0bc
H627	196.0d	12.0d	50.0h	32.4c	40.0bcd	138.0d
H628	198.0d	8.0c	54.0j	37.2d	49.0bcd	134.0cd
KSTP'94	137.0b	6.0bc	46.0e	21.3a	26.0a	135.0cd
No. 8	146.0b	2.0a	37.0c	20.0a	31.0ab	118.0a
PHB3253	102.0a	3.0ab	51.0i	21.3a	36.0abc	140.0d

Table 6: Performance of ten varieties in Malava division

	[1]Mean value for the trait					
Variety	[2]Ear height (inches)	[2]Bare tips	[2]Ear rot severity %	[2]Rot incidence %	[2]Borer incidence %	[2]Dropping ears
H513	89.0a	13.0a	54.0c	13.0a	14.0a	82.0a
H614	152.0cd	24.0bc	53.0b	22.0bc	25.0c	105.0def
H622	127.0b	27.0c	56.0d	25.0de	24.0c	98.0bcd
H625	153.0cde	27.0c	56.0d	24.4d	26.0c	115.0g
H626	145.0c	29.0c	56.0d	27.0d	28.0d	99.0cde
H627	162.0de	38.0d	53.0b	32.0f	26.0c	112.0fg
H628	168.0e	40.0d	60.0g	34.0f	27.0c	109.0fg
KSTP'94	99.0a	20.0b	59.0f	21.0bcd	18.0b	93.0bc
No. 8	114.0b	19.0ab	51.0a	17.0a	16.0ab	90.0ab
PHB3253	86.0.0a	20.0b	57.0e	15.0a	15.0a	108.0efg

[1]Numbers are means of four replicates

[2]Numbers followed by the same letter are not significantly different (P= 0.05)

This significantly (P=0.05) differed with all the other varieties except H625 (Table 33 and appendix 114). Open ear tips differed among harvest times and also varieties. The highest open ear tips were in variety H627 and were different from all varieties except H628. Borer incidence was significantly (P=0.05) different between varieties and not harvest intervals. Variety H627 and H625 (26%), H628 (27%) and H626 (28%) recorded the highest borer incidences (Table 6). Correlation analysis of ear rot incidence and borer incidence was found to be average and r = 0.48.

DISCUSSION

The results show that a relationship exists between ear rot and time of harvest. This association was evident in both Malava and Tongaren division. The results from the two divisions showed that there was an increase in rotting whenever harvesting was delayed. Disease severity differed significantly between varieties and time indicating that the varieties used have different susceptibilities to ear rot fungi and also it may be due to initially symptoless ear rot infection that don't seem to be visually distinct but as maize is left in the farm favourable conditions for ear rot proliferation make the fungi to spread and cover the kernels with its mycelia. The increase in incidence of ear rot fungi in all varieties over the three HTPs in both Tongaren and Malava was highest at the 12th week HTP and could be ascribed to proliferation of the fungi by either spore germination or mycelial growth owing to favorable field conditions. Though some varieties like H614 are reputed to be resistant to ear rot, delayed harvesting still compromised the quality of its grains. A study in New

Zealand revealed that delayed harvesting could ruin the grain quality in both susceptible and resistant varieties and lead to increased mycotoxins [12].

The occurrence of ear rot even when maize is harvested early could be due to high inoculum density of the ear rot pathogen in maize fields given that the crop is grown annually and also due to the multiple infection courts associated with it ear rot fungi [13]. Such infection courts that include roots, seeds, silk and through kernel damage by insects [2, 14-17] make control of the disease difficult. The lack of host specialisation reported in some of the maize ear rot fungi [18] makes it difficult for any maize variety to habour resistant genes against ear rot. Some forms of the resistance to ear rot appear to slow down the spread of the disease on kernels but do not prevent infection [19]. Such resistance could be useful in managing ear rots within an integrated strategy context like timely harvesting.

The differences in ear rot disease incidence between the two locations indicates that environmental factors prevailing in the maize growing region are important in determining development of ear rot. This location-variety interaction also indicates that genetic susceptibility of a cultivar to ear rot infection is not an absolutely stable characteristic but could be influenced by environmental conditions. In general, conditions favoring ear rot fungi have been described as warm and wet [19-21]. Though there is some climatic variation between the two sites, the weather can still be described as warm and wet. Increased ear rotting with HTPs was possibly due to continued colonization of maize kernel by ear rot fungi after initial infection.

Farmers in the region leave their maize in the field beyond physiological maturity to allow it to dry in order to facilitate direct storage into the store without sun drying. But if it rains while the grains are in the field, kernels may be subjected to infection by fungi [22]. Under high humidity, initially dry seed develops water content conducive to ear rot contamination [23]. Substrate moisture content and temperature dictate the extent of contamination [20]. When crops are exposed, to favorable conditions after maturation, ear rot contamination proceeds in absence of either management intervention or highly effective microbial competitors [23]. Whereas delayed harvesting may exacerbate the problem of ear rot, harvesting at physiological maturity when moisture content is high increases the risk of mould contamination during post harvest handling [24,25].

Delayed harvesting increases lodging incidences that allow ears to touch the ground especially in varieties that place their ears higher. Higher ear placement in avariety raises the center of gravity of the plant and hence make it unstable and prone to lodging. Maize lodging has been shown to provide an opportunity for ear damage and/or infection [26]. On touching the ground in a rainy period, favourable temperature and humidity set in and influence fungal colonization. The same climatic conditions also influence the extent to which crops become wounded by mammals, birds and insects. Lodging has been shown to distinctly influence in increasing deoxynevalenol (more than 65%) in barley and Orts, the results were found in samples from 49% of the plots with lodging compared with their pair none lodged plot [27].

In Tongaren division a strong correlation was established between ear rot incidence and borer incidence where as in Malava the correlation was average. From the data it was concluded that borers are an important predisposing factors of maize to ear rot pathogens in the two divisions. Early studies have shown that, *Busseola fusca* increases incidence of kernel infection by S*ternocapella maydis and* A. flavus followed by subsequent contamination by mycotoxins [28,29]. Susceptible crops damaged during development become highly infected by ear rots [30-32]. Some of the insects also carry spore of mycotoxin producing fungi [14] and specific insect/crop combinations have been repeatedly linked to mycotoxin contamination [33]. In maize corn borers on maize have been linked to aflatoxins, the same has been shown with the pink bollworm on cotton, lesser corn stalk borer on peanut and the navel orange worm on pistachio [32, 34-38].

Previous studies on maize from Western Kenya have readily isolated various ear rot fungi that include *F. verticillioides*, *F. graminearum, F. subglutinans, S. maydis, A. flavus and, A. parasiticus.* Both symptomless and rotten maize have shown ear rot contamination [2, 39,40]. Though mycological analysis is not reported in this work, isolation of many fungal species confirms that the fungi co-occur on maize kernels and there is a possibility of having more than one mycotoxin in a single maize sample from W. Kenya. Mycotoxins are fungal metabolites present in a variety of agricultural products/produce capable of having acute toxic, carcinogenic, mutagenic, teratogenic, immuno-toxic and oestrogenic effects to man and animals [6,44]. There exists abundant evidence that the inhabitants of sub Saharan Africa are exposed to high levels of mycotoxins [42] and epidemiological mycotoxin studies on humans have associated lethality of several diseases due to intake of mycotoxin contaminated food including liver cancer, hepatitis B & C, malnutrition, immunosuppression, vomiting, abdominal pain, malaria, impaired growth, reduced salivary secretary IgA levels, derangement of blood clotting mechanism, icterus and death [43-46].

In Kenya, the diet is mainly maize based with a 400 g average daily intake per person. Previous studies have detected several mycotoxins in both clean and rotten maize from kenya among them fumonisins, aflatoxins, moniliformin, deoxynivalenol and zearalenone [2,39,40,47]. Though Kenya has established the minimum tolerance levels for mycotoxins through the Kenya Bureau of Standards (KEBS) implementation of the standards has not been effectively executed. The country has frequently experienced aflatoxicoses. One of the most severe episodes of human aflatoxicoses in history was the 2004 outbreak of acute aflatoxicoses in Eastern Kenya, where a total of 317 cases were reported and a case fatality rate of 39% recorded [48,49]. It is therefore important for farmers to harvest maize timely and offer good post harvest handling practices to avoid proliferation of ear rot fungi and accumulation of associated mycotoxins

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