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Full Length Research Paper

Grain yield, stem borer and disease resistance of new maize hybrids in Kenya

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Evaluation of 30 maize hybrids for yield and resistance to stem borers and foliar diseases in four agro-ecologies in Kenya was conducted in 2009. There were significant differences among the hybrids in leaf damage, number of exit holes, tunnel length and grain yield in Kiboko. The maize hybrids CKPH08014, CKPH08025, and CKPH08026 showed the least leaf damage, exit holes and tunnel length, similar to the resistant check. Although ten hybrids yielded over 8 t/ha, two hybrids, CKPH09001 and CKPH08033, gave the highest yield of 8.99 and 8.86 t/ha, respectively, in Kiboko. There were significant differences among the hybrids in resistance to leaf rust and maize streak virus in Kakamega. The intensity of foliar diseases was high in Kakamega compared to the other sites. All hybrids appeared resistant to the foliar diseases at Kakamega. On the average, the highest yield of the hybrids was recorded in Kiboko (7.5 t/ha) followed by Kakamega (6.1 t/ha), and the least at Embu (3.5 t/ha), and Mtwapa (3.14 t/ha). The performance of the hybrids varied from site to site, with CKPH09002 and CKPH09003 performing well at Mtwapa, CKPH09001 at Kiboko, CKPH08039 at Embu, CKPH 08002 and CKPH08010 at Kakamega.

Key words: Host plant resistance, maize, pest management, stem borer, foliar disease.

INTRODUCTION

Maize (*Zea mays* L.) is one of the most important food staples in sub-Saharan Africa, providing food and income to over 300 million resource-poor smallholders. Its cultivation spans the entire continent and it is the dominant cereal food crop in many countries, accounting for 56% of total harvested area of annual food crops and 30-70% of total caloric consumption (FAOSTAT, 2007). The per capita consumption is highest in southern Africa, averaging about 181 kg in Malawi, 195 kg in South Africa, 168 kg in Zambia, and 153 kg in Zimbabwe (Hassan et al., 1998).

Among pests, stem borers reduce maize yield in Africa through damaging the leaves, stem, ears, and kernels. The spotted stem borer, *Chilo partellus* Swinhoe (Crambidae) and the African stem borer *Busseola fusca* Fuller (Noctuidae) are the most important lepidopteran stem borer species. In Kenya, they cause significant annual losses in maize estimated by farmers at 12.9% and through crop loss trials at 13.5% (De Groote et al., 2004), worth US $91 million.

Application of chemical insecticides has been recommended in order to protect plants against the stem borers. However, in addition to posing health problems, insecticides are frequently unavailable or too expensive for subsistence farmers in Africa. Therefore, an environmentally safe and economically feasible stem borer control practice needs to be available. Host plant resistance is a practical and easy to adopt and use method of stem borer control. Developing high yielding maize varieties that are insect resistant will considerably minimize the overall cost of production. In an effort to design effective and efficient methods to control the maize pests, the International Maize and Wheat Improve-

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Abbreviations: CIMMYT, International Maize and Wheat Improvement Center; **KARI,** Kenya Agricultural Research Institute; **ICIPE,** International Center for Insect Physiology and Ecology; **MSV,** maize streak virus; **MBR,** multiple borer resistant; **SWCB,** Southern corn borer; **SCB,** sugarcane borer; **ECB,** European corn borer; **FAW,** fall armyworm.

Table 1. Description of the trial site.

Site	Longitude	Latitude	Elevation (m)	Rain (mm)	Temp. (min.)	Temp. (max.)	Soil texture
Kiboko	$37^0$75'E	$2^0$715S'	975	530	14.3	35.1	Sandy clay
Embu	$37^0$42'E	$0^0$449'	1510	1200	14.1	25.0	Clay loam
Kakamega	$34^0$45'E	$0^0$16'N	1585	1916	12.8	28.6	Sandy loam
Mtwapa	$39^0$44'E	$3^0$50'S	15	1200	22.0	30.0	Sandy soils

Table 2. Visual scoring scale (1-9) of stem borer foliar damage.

Scale (1-9)	Description	Resistance reaction
1	No visible leaf feeding damage	Highly resistant
2	Few pin holes on older leaves.	Resistant
3	Several shot-holes injury on a few leaves.	Resistant
4	Several shot-hole injuries common on several leaves or small lesions.	Moderately resistant
5	Elongated lesions (> 2 cm long) on a few leaves.	Moderately resistant
6	Elongated lesions on several leaves.	Susceptible
7	Several leaves with elongated lesions or tattering.	Susceptible
8	Most leaves with elongated lesions or severe tattering.	Highly susceptible
9	Plant dying as a result of foliar damage.	Highly susceptible

Source: Adapted from CIMMYT (1989).

ment Center (CIMMYT), is developing and deploying resistant, high yielding, and adapted maize hybrids and open-pollinated varieties through conventional breeding. This paper, therefore, reports yield performance and resistance of new maize hybrids to stem borers and foliar diseases in four different agro-ecologies of Kenya.

MATERIALS AND METHODS

Trial sites

The trial was conducted in Kenya at four sites representing different maize growing ecologies: Mtwapa, Kiboko, Kakamega and Embu, during the 2009 main planting season (Table 1). Embu is located in a dry transitional zone, Kakamega in moist transitional, Kiboko in dry mid-altitude, while Mtwapa is in a low land coastal tropic.

Experimental design and management

The design was an alpha lattice of 6 entries by 5 blocks with 3 replications. Two seeds were planted per hill in a row of 5 m length and thinned to one seedling per hill 2-weeks after emergence. There were two rows per plot. The row-to-row distance was 75 cm while plant-to-plant distance was 25 cm, giving a plant density of 53,000 plants/ha. Fertilizers were applied to give 60 kg N and 60 kg P_2O_5/ha as recommended for the area. Top dressing was done using nitrogen fertilizers in two splits. Supplemental irrigation was applied when needed. The fields were kept free of weeds by hand weeding. A total of 30 hybrids were planted including susceptible and resistant checks. Planting was done in March 2009.

Artificial infestation with stem borers

First instar larvae (neonates) of *C. partellus* were obtained from the Kenya Agricultural Research Institute (KARI), Katumani stem borer mass rearing laboratory; whilst *B. fusca* neonates were obtained from the International Center for Insect Physiology and Ecology (ICIPE), Nairobi, Kenya. The trials at Kiboko were infested with *C. partellus* and trials at Embu infested with *B. fusca*. Three weeks after seedling emergence, each row was divided using a string into two un-equal portions where each of the five plants in the front part was infested with five neonates. The back part consisting of 14 maize plants were protected using Beta-cyfluthrin 0.5 g/kg granules, which is a systemic insecticide and a synthetic pyrethroid marketed as Bulldock® 0.05 GR. Trials planted at Mtwapa and Kakamega were left for natural infestation by the stem borers, *C. partellus* and *B. fusca*, respectively.

Stem borers infested plants

Foliar damage for stem borer was assessed by scoring each infested plant on a 1-9 scale; where 1= no visible damage and 9 = completely damaged (Table 2). Plants with a leaf damage score of 0–3 were rated highly resistant, 3.1–5.0 moderately resistant, 5.1-6.0 susceptible and 6.1-9.0 as highly susceptible (CIMMYT, 1989). The number of stem borer exit holes per plant was counted at harvest. The cumulative tunnel length was measured after splitting the stems of each of the infested plants.

Foliar diseases

The foliar diseases including, rust *Puccinia sorghi*, Gray leaf spot *Cercospora zeae maydis*, and leaf blight *Exerohilium turcicum* were recorded for disease severity on all plants per plot using a 1–5 scale where 1= no symptom on leaves, 2 = light disease symptom on leaves, 3 = moderate symptoms on leaves, 4 = severe symptom on 60% of leaf area, 5 = severe symptom on 75% or more of the leaf area. The maize streak virus (MSV) severity was rated on all plants per plot using a 1–5 scale with half points where 1 =no symp-

Table 3. Mean leaf and stem damage by *Chilo partellus* and grain yield of maize hybrids at Kiboko.

Entry no.	Pedigree	Leaf damage (1-9)	No. of exit holes	Tunnel length (cm)	Grain Yield (t/ha)
1	CKPH09001	2.0	0.8	2.7	9.0
2	CKPH08032	2.3	1.2	2.8	8.4
3	CKPH09002	1.9	0.7	2.1	8.5
4	CKPH08033	1.8	0.8	2.2	8.9
5	CKPH09003	1.8	0.6	1.9	7.6
6	CKPH08035	2.0	1.2	3.2	7.6
7	CKPH08036	1.9	0.8	2.1	8.6
8	CKPH08037	2.0	1.1	3.4	8.6
9	CKPH08038	2.1	1.7	4.7	8.3
10	CKPH08039	2.1	1.0	3.0	8.2
11	CKPH08040	2.1	1.3	5.0	8.6
12	CKPH08041	1.8	0.8	1.8	8.4
13	CKPH08043	2.2	1.0	2.1	8.0
14	CKPH08044	1.6	0.5	1.8	6.7
15	CKPH08002	1.8	0.4	1.4	7.7
16	CKPH08003	1.5	0.6	2.0	7.4
17	CKPH08004	1.6	0.8	2.0	6.8
18	CKPH09004	1.8	0.3	0.8	6.6
19	CKPH08009	1.5	0.6	2.0	6.5
20	CKPH08010	2.1	0.9	0.8	7.1
21	CKPH08012	1.8	0.7	1.3	6.3
22	CKPH08014	1.3	0.2	0.2	6.7
23	CKPH08020	1.7	0.5	1.6	6.4
24	CKPH08024	1.7	0.7	2.1	7.5
25	CKPH08025	1.3	0.0	0.3	6.8
26	CKPH08026	1.4	0.1	0.5	6.9
27	CKPH08028	1.6	0.4	1.4	7.6
28	WH505	2.7	2.0	3.7	7.5
29	Check (resistant)	1.1	0.1	0.2	6.3
30	Check (susceptible)	3.5	1.5	3.7	6.5
Mean		1.8	1.8	2.1	7.5
LSD		0.6	0.9	2.2	1.2
Significance		**	*	*	**

tom on leaves, 1.5 = very few streaks on leaves, 2 = light streak on old leaves, gradually decreasing on young leaves, 2.5 = light streaking on an old and young leaves, 3 = moderate streaks on old and young leaves, 3.5 = moderate streaks on old and young leaves and slight stunting, 4 = severe streaking on 60% of leaf area, plants stunted, 4.5 = severe streaking on 75% of leaf area, plants severely stunted, 5 = severe streaking on 75% or more of the leaf area, plants severely stunted, dying or dead. No artificial inoculations were carried out for the diseases as natural infestation was assumed to occur every year. Gray leaf spot, leaf rust and leaf blight were recorded only at Kakamega, a hot spot area, for major maize diseases. Maize streak virus disease was recorded across the sites except at Kiboko.

Yield

At physiological maturity, all plants were harvested excluding one border plant from both ends, and the artificial infested five plants with larvae of stem borers. Ears from each plot were shelled separately, and the grain weight taken at moisture content of 13%, and was converted to yield per hectare.

Statistical analysis

The exit holes were angular transformed (arcsine $\sqrt{\text{proportion}}$) in order to stabilize the variance before subjecting them to analysis of variance (ANOVA). Foliar damage for stem borer and diseases and yield data were not transformed. All data were subjected to ANOVA using Statistical Analysis Software (SAS, 2003) and the means separated using least significant difference (LSD) at ($P < 0.05$).

RESULTS AND DISCUSSION

There were significant differences ($P < 0.05$) between the hybrids in leaf damage, exit holes, tunnel length and grain yield in Kiboko (Table 3). The hybrids, CKPH08014, CKPH08025, CKPH08026, and the resistant check had

Table 4. Mean *C. partellus* damage (leaf damage, exit holes, tunnel length) disease severity (maize streak virus) and grain yield at Mtwapa.

Entry No.	Hybrid	Leaf damage (1-9)	No. of exit holes	Tunnel length (cm)	Maize streak virus (1-5)	Grain yield (t/ha)
1	CKPH09001	1.4	0.6	1.0	0.2	2.6
2	CKPH08032	1.2	1.6	10.1	0.0	2.9
3	CKPH09002	1.4	1.9	10.8	1.0	3.2
4	CKPH08033	1.4	0.6	2.0	0.0	2.9
5	CKPH09003	1.2	0.8	4.4	1.2	3.1
6	CKPH08035	1.1	0.2	1.1	1.7	1.9
7	CKPH08036	1.0	1.0	4.2	0.3	2.9
8	CKPH08037	1.3	0.7	4.6	0.5	2.9
9	CKPH08038	1.4	1.2	12.6	0.6	2.6
10	CKPH08039	1.3	0.9	6.0	0.2	2.5
11	CKPH08040	1.4	0.8	3.8	1.2	2.4
12	CKPH08041	1.5	0.7	6.0	0.4	2.6
13	CKPH08043	1.1	1.0	5.9	0.6	2.6
14	CKPH08044	1.1	1.5	8.2	0.0	2.6
15	CKPH08002	1.1	0.1	0.5	1.4	2.3
16	CKPH08003	1.4	0.5	5.2	0.2	2.3
17	CKPH08004	1.5	1.0	8.8	0.5	2.0
18	CKPH09004	1.0	0.9	0.8	0.0	1.7
19	CKPH08009	1.5	0.2	3.4	0.0	2.0
20	CKPH08010	1.3	1.5	5.8	0.1	1.7
21	CKPH08012	1.2	0.6	2.1	0.1	1.9
22	CKPH08014	1.4	0.8	1.8	0.5	2.2
23	CKPH08020	1.1	0.6	4.3	1.1	1.6
24	CKPH08024	1.1	0.8	4.8	0.2	1.9
25	CKPH08025	1.5	1.0	5.4	0.0	1.9
26	CKPH08026	1.1	0.7	3.9	0.9	2.1
27	CKPH08028	1.3	0.5	5.3	0.2	2.6
28	WH505	1.2	0.2	4.8	0.7	2.2
29	Check (resistant)	1.5	1.4	8.6	0.5	1.6
30	Check (susceptible)	1.1	1.1	8.2	0.4	3.1
Mean		2.3	0.8	5.1	0.4	2.4
LSD		-	-	-	-	0.8
Significance		ns	ns	ns	ns	*

the least leaf damage, exit holes and tunnel length, compared to the remaining hybrids. However, the hybrid WH505, and the susceptible check had the highest leaf damage, exit holes and tunnel length. Although ten hybrids yielded over 8 t/ha, two hybrids—CKPH09001, CKPH08033—gave the highest yield of 8.99, and 8.86 t/ha, respectively. There were significant differences ($P < 0.05$) between the hybrids in yield at Mtwapa (Table 4) and in leaf damage at Embu (Table 5). The resistant check yielded the least (6.29 t ha^{-1}). There were significant differences ($P < 0.05$) between the hybrids in resistance to leaf rust and the maize streak virus in Kakamega (Table 6). The intensity of the diseases was high in Kakamega compared to the rest of the sites. The hybrids, CKPH09001, CKPH09002, CKPH09003, CKPH08044, CKPH08024 and CKPH08026, had relatively high infection with MSV, but all the new hybrids including the checks were resistant to leaf blight (Table 6).

However, on average all hybrids appeared resistant to the foliar diseases: gray leaf spot, leaf rust, leaf blight and maize streak virus, at all sites. The resistant check produced the highest yield at Mtwapa and the least at Embu. On average, the highest yield of the hybrids was recorded in Kiboko (7.5 t/ha) followed by Kakamega (6.1 t/ha), and the least at Embu (3.5 t/ha), and Mtwapa (3.14 t/ha).

This study evaluated yield performance and reaction of 30 maize hybrids to stem borers *C. partellus* and *B. fusca* in different agro-ecologies in Kenya.

Table 5. Mean *B. fusca* damage (leaf damage, exit holes, tunnel length), disease severity (maize streak virus) and grain yield of maize hybrids at Embu.

Entry No.	Hybrid	Leaf damage (1-9)	No. of exit holes	Tunnel length (cm)	Maize streak virus (1-5)	Grain yield (t/ha)
1	CKPH09001	3.1	0.1	0.3	0.3	3.6
2	CKPH08032	2.9	0.5	1.7	0.4	4.0
3	CKPH09002	2.8	0.2	1.0	0.2	3.5
4	CKPH08033	2.7	0.3	1.0	0.0	4.4
5	CKPH09003	2.9	0.1	0.5	0.4	4.3
6	CKPH08035	2.8	0.3	0.1	0.1	3.4
7	CKPH08036	2.9	0.2	0.8	0.0	4.5
8	CKPH08037	3.3	0.2	1.4	0.1	3.2
9	CKPH08038	3.1	0.0	0.2	0.2	3.7
10	CKPH08039	2.7	0.4	2.0	0.1	4.8
11	CKPH08040	2.8	1.3	3.9	0.0	3.4
12	CKPH08041	2.9	0.1	0.4	0.0	4.1
13	CKPH08043	2.8	0.3	1.1	0.0	2.6
14	CKPH08044	2.6	0.1	0.5	0.2	2.9
15	CKPH08002	2.9	0.2	1.0	0.4	4.2
16	CKPH08003	2.3	0.4	1.6	0.0	3.9
17	CKPH08004	2.5	0.3	0.8	0.2	2.5
18	CKPH09004	2.4	0.2	0.1	0.7	3.2
19	CKPH08009	2.4	0.2	1.0	0.0	3.2
20	CKPH08010	2.7	0.2	1.0	0.1	3.3
21	CKPH08012	2.5	0.1	0.5	0.1	2.4
22	CKPH08014	2.7	0.5	0.7	0.2	3.2
23	CKPH08020	2.5	0.2	0.8	0.0	3.3
24	CKPH08024	2.4	0.2	0.9	0.5	3.0
25	CKPH08025	2.3	0.2	0.7	0.1	2.6
26	CKPH08026	2.8	0.2	0.7	0.0	3.8
27	CKPH08028	2.9	0.0	0.7	0.0	3.3
28	WH505	3.2	0.0	0.3	0.0	3.3
29	Check (resistant)	2.7	0.2	0.8	0.1	2.5
30	Check (susceptible)	2.7	0.2	0.1	0.0	3.1
Mean		4.7	0.2	0.8	0.1	3.5
LSD		0.5	-	-	-	-
Significance		*	ns	ns	ns	ns

Insect resistance, grain yield and the associated agronomic characters measured were strongly controlled by additive gene action. Resistant maize varieties provide an inherent control that involves no environmental problems, and they are generally compatible with other insect-control methods. The cultivation of resistant maize crop is not subject to the vagaries of weather as are chemical-control measures, and in certain circumstances, it is the only effective means of control. Resistant varieties control even a low insect pest density, whereas insecticide use is justifiable only when the density reaches the economic injury level (Kfir et al., 2002).

The stem borer attack on maize commences at the whorl stages (3–4 leaf stage) and causes three types of damage to maize, foliar damage, 'dead hearts' (death of growing points) and stem tunneling. All the three components are important in distinguishing the suscep-tible and resistant cultivars of maize. Large number of maize genotypes with resistance to *C. partellus* has been reported (Kumar, 1993); the most notable sources of resistance to *C. partellus* are Antigua Group 1, Population 590 (Multiple Borer Resistant Tropical, MIRT) of CIMMYT, and several inbred lines from Mississippi (Mp704, Mp705, mp706, Mp708) and CIMMYT (CML67, CML69, CML139).

The yield performance of the hybrids was best at Kiboko and least at Mtwapa. However, the yield performance of the hybrids varied from site to site, with CKPH09002 and CKPH09003 performing well at Mtwapa, CKPH09001 at Kiboko, CKPH08039 at Embu,

Table 6. Mean *B. fusca* damage (leaf damage, exit holes, tunnel length), disease severity (gray leaf spot, leaf rust, leaf blight and maize streak virus) and grain yield of maize hybrids at Kakamega.

Entry No.	Hybrid	Leaf damage (1-9)	No. of exit holes	Tunnel length (cm)	Gray leaf spot (1-5)	Leaf rust (1-5)	Leaf blight (1-5)	Maize streak virus (1-5)	Grain yield (t/ha)
1	CKPH09001	0.7	1.7	2.2	2.5	3.8	1.7	0.7	6.3
2	CKPH08032	0.9	1.6	2.2	2.8	2.6	1.6	0.9	6.6
3	CKPH09002	1.2	1.5	1.9	2.7	6.0	1.5	1.2	4.6
4	CKPH08033	1.0	1.7	1.4	2.4	2.9	1.7	1.0	5.6
5	CKPH09003	0.4	1.7	2.2	2.6	0.3	1.7	0.4	6.2
6	CKPH08035	1.1	1.7	1.9	2.6	1.5	1.7	1.1	6.6
7	CKPH08036	1.1	1.4	1.7	2.5	0.2	1.4	1.1	5.6
8	CKPH08037	0.9	1.8	1.5	2.6	1.0	1.8	0.9	5.4
9	CKPH08038	1.5	1.6	1.6	2.7	1.2	1.6	1.5	5.8
10	CKPH08039	1.4	1.6	1.6	2.5	2.4	1.6	1.4	6.4
11	CKPH08040	1.1	1.8	1.4	2.9	2.3	1.8	1.1	6.8
12	CKPH08041	0.4	1.5	1.6	2.6	2.0	1.5	0.4	6.6
13	CKPH08043	1.5	1.7	1.6	2.8	2.4	1.7	1.5	6.5
14	CKPH08044	1.0	1.7	2.0	2.6	3.7	1.7	1.0	4.7
15	CKPH08002	0.6	1.8	2.4	3.0	1.4	1.8	0.6	7.4
16	CKPH08003	1.3	1.4	1.7	3.1	1.6	1.4	1.3	5.2
17	CKPH08004	1.0	1.5	1.7	2.8	1.4	1.5	1.0	5.0
18	CKPH09004	0.6	1.6	1.4	2.7	0.7	1.6	0.6	5.7
19	CKPH08009	0.8	1.8	1.9	2.5	0.1	1.8	0.8	7.2
20	CKPH08010	1.3	1.6	2.0	2.8	0.4	1.6	1.3	7.4
21	CKPH08012	0.8	1.4	1.7	2.6	2.8	1.4	0.8	6.4
22	CKPH08014	0.7	2.0	1.8	3.3	0.1	2.0	0.7	5.8
23	CKPH08020	0.8	1.7	1.8	2.6	0.7	1.7	0.8	6.7
24	CKPH08024	1.0	1.5	1.7	3.0	3.3	1.5	1.0	5.6
25	CKPH08025	0.5	1.5	2.0	2.9	0.4	1.5	0.5	6.0
26	CKPH08026	0.1	1.5	2.1	3.3	4.4	1.5	0.1	5.5
27	CKPH08028	0.5	1.9	1.9	3.0	2.1	1.9	0.5	6.9
28	WH505	1.2	1.5	1.6	3.2	0.8	1.5	1.2	7.0
29	Check (resistant)	0.7	1.5	1.4	2.8	1.3	1.5	0.7	5.5
30	Check (susceptible)	2.2	1.8	1.5	3.2	1.1	1.8	1.2	6.3
Mean		0.9	1.6	1.8	2.8	1.7	1.6	0.9	6.1
LSD		-	-	0.4	-	2.6	-	-	-
Significance		Ns	Ns	**	ns	**	ns	ns	ns

and CKPH 08002 & CKPH08010 at Kakamega. The fact that intensity of MSV was high in Kakamega (Table 6) than in Mtwapa and Embu (Tables 4 and 5) is attributed to environmental factors, particularly temperature and humidity. The epidemics of fungal diseases are reported to have been influenced by optimum temperature and high relative humidity. Maize streak virus (MSV), incited by maize streak geminivirus, is an important economic disease occurring in most sub-Saharan African countries. Maize streak virus is an obligate parasite, transmitted by viruliferous leafhoppers of the genus *Cicadulina* spp. Yield losses in maize due to maize streak range from a trace to virtually 100% when epidemics occur on susceptible open-pollinated varieties and hybrids (Barrow, 2000). The development of maize germplasm that is resistant to MSV has therefore been the goal of several breeding programs in Africa (Kuiper-Goodman, 1995). Several researchers have developed and released resistant populations and inbred lines (Anon, 1984; Barrow, 2000).

Conclusion

New stem borer resistant maize hybrids have been identified using artificial infestation and measuring leaf damage and stem tunneling as well as exit holes. The use of multiple borer resistant lines helps in identifying superior varieties for the resistance to stem borers which is a polygenic trait. These new resistant hybrids are additional sources of resistance and can be useful in future breeding efforts to deliver stem borer resistance into adapted varieties and hybrids where *C. partellus* and *B. fusca* are a major constraint for maize production.

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