Beneficial effects of bending maize plants at physiological maturity on lodging and on some pre-harvest grain quality parameters

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SUMMARY

In the study, maize plants (cv. Aburotia) bent, just below the lowest ear, at 2 weeks before physiological maturity (PM), at PM, and 2 weeks after PM were compared with unbent plants for grain moisture content, cob infestation with insects (adults and larvae), grain mouldiness, grain yield per cob, and incidence of lodging. The bending and no bending treatments were applied in a randomized complete block design with three replications. Relevant weather records during the study period were provided by the Kumasi Meteorological Station. Grain moisture content, cob infestation with adult insects, and extent of lodging were, at harvest, significantly lower (P=0.05) in bent plants than in unbent ones. Among the bent plants, these parameters decreased with early bending. Moisture content of grains from plants bent 2 weeks before PM, at PM, and 2 weeks after PM, for example, were, at harvest, 23.3, 25.3, and 31.7 per cent, respectively, compared to 38.3 per cent recorded for unbent plants. Similarly, while only 1 - 2 plants/m^2 lodged on plots with bent plants, an average of 5 plants/m^2 lodged on plots with unbent plants. Cob infestation with stemborers/earworms, incidence of mouldiness, and grain damage per cob, also, were lower in bent than in unbent plants. Dry weight of marketable grains per cob was significantly highest (79.85 g/cob) in plants bent at PM and lowest (71.35 g/cob) in plants bent 2 weeks earlier. These results indicate that the bending over of maize plants has crop protection value. They further show that the ideal developmental stage to bend plants to combine the benefits of reduced pre-harvest grain moisture contents and field losses with maximum grain yield is at PM.

RÉSUMÉ

AWUAH, R. T.: *Les effets salutaires de la flexion des plantes de maïs à maturité physiologique sur l'abbatage et sur quelques paramètres de la qualité de graine à la prémoisson.* Dans l'étude les plantes (cv. Aburotia) courbées, juste au-dessous de l'épi le plus bas, à 2 semaines avant la maturité physiologique (MP), à MP et à 2 semaines après MP étaient comparées aux plantes non-courbées en ce qui concerne le contenu d' humidité de graine, l' infestation d' épi par les insectes (les adultes et les larves), la moisissure de graine, le rendement de graine par épi et l'incidence de l'abbatage. Les traitements de courbure et de nulle courbure étaient appliqués dans un projet de bloc complet choisi au hasard avec trois répartitions. Les enregistrements météorologiques utiles pendant la période de l'étude étaient obtenus de la station météorologique de Kumasi situé à 5 km de la zone de l'étude. Le contenu d'humidité de graine, l'infestation d'épi par les insectes et le mesure d'abbatage étaient considérablement plus bas (P = 0.05) dans les plantes courbées que dans les non-courbées. Parmi les plantes courbées, ces paramétres diminuaient avec la courbure tôt. Le contenu d'humidité des graines de plantes courbées 2 semaines avant MP, à MP et 2 semaines aprés MP par exemple, étaient, à la moisson respectivement 23.3, 25.3 et 31.7, comparés à 38.3 pour cent enregistré pour les plantes non-courbées. De la même façon tandis que seulement 1-2 plantes/m^2 étaient abbatues sur les terrains avec les plantes courbées, un moyen de 5 plantes/m^2 abattues sur les terrains avec les plantes non courbées. Les infestations d'épi avec les insectes térébrants/vers d'épi, l'incidence de moisissure et les dégât de graine par épi, aussi, étaient plus faible dans les plantes courbées que dans les plantes non-courbées. Les poids sec de graine vendable par épi était considérablement le plus élevé (79.85g/ épi) dans les plantes courbées à l'étape de MP et

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le plus faible (71.35g/ épi) dans les plantes courbées 2 semaines précédemment. Ces résultats indiquent que la courbure des plantes de maïs a une valeur de protection des cultures. Ils montrent davantage que l'étape de croissance idéale de courber les plantes afin de combiner les avantages des niveaux d'humidité réduite de la graine de prémoisson et les pertes aux champs avec le rendement maximum de graine est à l'étape de MP.

Introduction

Deterioration of maize (*Zea mays* L.) during storage is a major production constraint, especially in warm and humid environments. The problem often originates from the field (Whitehead & Calvert, 1959; Danraj, 1964; Mislivec & Tuite, 1970) and a relationship has been shown to exist between pre-harvest insect damage to maize grains and fungal infection, especially by *Aspergillus flavus* Link ex Fries (Widstrom, 1979; Guo *et al.*, 1995), resulting in reduced kernel quality and potential aflatoxin contamination of the kernels during storage. Maize contaminated by aflatoxins is unfit for consumption because of the health hazards posed by the toxins (Enomoto & Saito, 1972; Chen, 1992). It is essential, therefore, to minimize pre-harvest kernel damage and mouldiness if enhanced storability is desired, more so when it is well established that the initial field damage indicates how well a given maize sample will store (Qasem & Christensen, 1960).

In Ghana, the major season (April - August) maize crop contributes significantly to total national production, and matures during a period when rainfall is generally high and the weather humid. Grain moisture content at harvest is usually about 30 per cent. To decrease post-harvest mould growth and enhance storability, farmers are advised to dry the crop down to 9 - 11 per cent moisture content (MOFA, 1989). This is often difficult to do, because farmers generally lack the resources to rapidly dry the crop to low moisture content, especially from the high pre-storage moisture contents. In addition to minimizing pre-harvest kernel damage, ways must, therefore, also be found to reduce the pre-harvest grain moisture contents to facilitate open air drying, which is commonly used by most maize farmers in Ghana.

The maize plant could be manipulated to reduce pre-harvest kernel moisture contents. Awuah (1977) showed that by bending maize plants below the lowest ear at physiological maturity, reduced kernel moisture contents were possible. Pre-harvest incidence of mouldiness and infestation of kernels by insects were also minimized. However, it was a preliminary study, and the experimental design used did not permit satisfactory statistical analysis and comparison of the data.

This study therefore aimed to expand on and validate Awuah (1977) by showing conclusively the effects of bending maize plants at three different developmental stages, *viz.* 2 weeks before PM, at PM, and 2 week after PM, on (i) pre-harvest grain moisture content, (ii) cob infestation with adult insects, (iii) stemborer and earworm populations, (iv) incidence of grain mouldiness, and on (v) lodging. The effect of bending on the yield of marketable grains per cob was also determined.

Materials and methods

Study site, field layout, and plant establishment

The experiment was conducted from May to August, 1989 at the Department of Crop Science, KNUST, Kumasi. The soil was medium-textured, free-draining, and of the Kumasi series. The last crop grown on the land was maize, and this was followed by a fallow period of 6 months. The land was ploughed, harrowed, and an experimental area measuring 15 m × 15 m demarcated and worked into a fine tilth. The treatments were applied in a randomized complete block design with three replications. The blocks measured 15 m × 3.4 m (0.45 m between blocks). The plots were 3.6 m × 3.4 m large and were spaced 0.45 m on the blocks. The medium-maturing (105-110 days), high-yielding (4 t/ha), short - statured (1.6 m approx.), white dent maize cultivar, Aburotia, was sown on each plot at a spacing of 43 cm × 43 cm (three seeds per hole) and thinned to two seedlings per stand 1 week after emergence. Compound fertilizer (N-P-K; 15-15-15) was applied (261 kg/ha) 1 week later, followed by side dressing with ammonium sulphate (261 kg/ha) 2 weeks before tasselling. Weeds were hoed 2 and 8 weeks after sowing.

Experimental treatments

The treatments evaluated were (i) bending plants just below the lowest ear 2 weeks before PM, (ii) bending at PM, and (iii) bending 2 weeks after PM. The PM stage was determined by the visible presence of a black tissue layer at the tips of the kernels. During each period of bending, 45 plants from six middle rows on each plot were bent. In the control treatment, plants were left unbent.

Data and data analysis

Eleven days after the last bending, plants lodged within a 2.58 m × 2.15 m area on each plot were counted and the number expressed on a metre basis. Concurrently, 20 ears were randomly harvested, dehusked inside a large polyethylene bag, fumigated with chloroform to kill insects, and five parameters determined and expressed on a cob basis: (i) number of adult insects, (ii) number of earworms/stemborers, (iii) number of damaged grains (by birds and insects), (iv) number of mouldy grains, and (v) fresh weight of marketable grains. Moisture content of representative shelled grains from each plot was also determined gravimetrically. From the moisture content and kernel fresh weight values, kernel dry weight per cob was calculated for all treatments. Data were subjected to ANOVA and mean separation determined with the Least Significance Difference (LSD) test.

Rainfall, temperature, and relative humidity records for Kumasi during the study period were provided by the Kumasi Meteorological Station, located about 5 km from the experimental site.

Results

Table 1 summarizes the results of the study. Significantly more plants ($P = 0.05$) were lodged per m^2 on plots with unbent plants than on those with bent plants. While only 1 plant/m^2 lodged in plants bent 2 weeks before PM, 5 plants/m^2 lodged when plants were left unbent. No significant differences in lodging, however, were detected among the bent plants. Cobs from unbent plants had significantly higher ($P = 0.05$) numbers of adult insects (mainly *Sitophilus zeamais* Motsch. and predacious earwigs) than those from bent plants. Among the bent plants, the highest adult insect population of 1.37 per cob was recorded from plants bent 2 weeks after PM. A value of 2.15 adult insects per cob was associated with unbent plants.

TABLE 1

The Effect of Bending Maize Plants on Plant Lodging and Other Pre-harvest Grain Quality Parameters

*Stage of bending plants**	*Adult insects/cob*	*Earworms and stemborers/cob*	*% grain moisture*	*Dry wt/cob (g)*	*Mouldy grains/cob*	*Damaged grains/cob*	*Plants lodged/m^2*
2 weeks before PM	0.73	0.78	23.30	71.35	6.00	7.47	1.00
At PM	0.87	0.83	25.30	79.85	10.00	8.03	2.00
2 weeks after PM	1.37	0.93	31.70	73.93	11.00	8.33	2.00
Unbent plants (control)	2.15	0.97	38.30	70.09	14.00	9.77	5.00
LSD ($P \geq 0.05$)	0.49	NS	6.30	4.91	7.42	NS	1.91

*PM = Physiological maturity (black layer stage).

Earworm/stemborer numbers and damaged kernels/cob, though higher in unbent plants, were not significantly different ($P = 0.05$) from those associated with bent plants. Significantly fewer mouldy grains were associated with plants bent 2 weeks before PM compared to those from unbent plants. Generally, mouldy grains were associated with insect and bird damage, but a few undamaged kernels were mouldy. *Aspergillus, Penicillium,* and *Rhizopus* species were isolated in high frequency from the mouldy grains.

Grain moisture content in bent plants increased from 23.3 per cent in plants bent 2 weeks before PM to 31.7 per cent in those bent 2 weeks after PM. These values were both significantly lower ($P = 0.05$) than the value of 38.3 per cent associated with kernels from unbent plants. The highest dry matter yield of grains/cob was 79.85 g, and this was recorded in plants bent at PM. Significantly lower values of 70.09, 71.35, and 73.93 g/cob were, respectively, associated with unbent plants, plants bent 2 weeks before PM, and plants bent 2 weeks after PM.

Birds were often seen feeding on grains from the tips of ears on unbent plants. None was seen feeding on ears on bent plants. Grain loss was, therefore, considerable in unbent plants.

The total amount of rainfall recorded in Kumasi after plants were bent was 131. 03 mm. Of this, 14.03 mm was recorded between 27th and 31st July, and 117 mm during August. Much of the rainfall in August was in torrents about 2 weeks before harvest. The average relative humidities during the periods were, respectively, 85.5 and 80 per cent. The average temperatures were 25.68 and 25 °C.

Discussion

The benefits of bending maize plants reported earlier by Awuah (1977) were confirmed by this study. The study has also verified as sound the practice among traditional maize farmers in southern Mexico who bend maize plants over to facilitate kernel drying and reduce pest attack in the field (Rivera, 1996). The most beneficial and direct effect of maize stalk bending was the significant reduction of grain moisture content. This was anticipated since downward-pointing ears (in bent plants) would not as readily permit entry of water as ears in upright positions. Tips of upward-pointing ears are exposed to the impact of raindrops which tend to force them apart. In ears lacking tight-fitting husks, entry of water *via* the tips could be substantial. In this study, periods of heavy rainfall preceding harvest contributed to raising kernel moisture content. Birds feeding from ear tips, an impossibility in bent plants, also caused considerable eartip shredding, which either permitted free entry of water or created reservoirs for water to accumulate and seep into the ears. Because of the lower moisture content of grains from bent plants, post-harvest drying to desirable moisture contents will require less resources and time.

The significant reduction in lodging associated with stalk-bending resulted from the stabilizing effect of reduced plant height in wind and wind-driven rains. Tall maize plants have a greater tendency to lodge (Duncan, 1975). This is undesirable in maize culture, as the ears often come into contact with soil, absorb moisture, and are more prone to deterioration. Besides, such ears are attacked more readily by rodents and insects.

The high moisture contents of grains from unbent plants and the expected high humidities within ears on such plants possibly contributed to the high incidence of adult insects in such ears as indicated by Apert (1987). The experiment could not detect significantly higher stemborer/earworm populations and higher grain damage in unbent plants compared to bent ones, probably because of early harvesting of the ear. In this study, it was not expedient to delay harvest, as this would have resulted in lodging of all plants on the "unbent" plots because of frequent wind-driven rains. Awuah (1977) recorded more stemborers and earworms on cobs from unbent plants than from bent plants as harvest was delayed. In that study, the incidence of lodging was low, and there were enough unbent plants in upright positions (as harvesting was delayed) whose ears could be used for analysis.

Incidence of grain mouldiness was lower in plants bent at PM and 2 weeks after PM, but the levels were not significantly different from those for unbent plants. As with the stemborer/earworm populations, a delay in harvesting would probably have enabled significant differences among the treatments to be detected. This is suspected to be so, since the higher moisture contents of grains from unbent plants and the expected higher humidities within their ears would favour infection by and a more rapid development of fungi that cause mouldiness (Koehler, 1969; Mislivec & Tuite 1970; Qasem & Christensen, 1960).

Although bending plants 2 weeks before PM was beneficial in adult insect infestation of the ears, incidence of kernel mouldiness, grain moisture content, and plant lodging, dry matter yield of grains per cob from such plants was low compared to that for plants bent at PM. Dry matter accumulation in maize grains is maximum at PM (Aldrich & Leng, 1968), and this should be the optimum developmental stage to bend plants to combine the benefits of reduced pre-harvest kernel moisture contents and reduced field losses with higher dry matter yields. Since most maize farms in Ghana are small to medium in size, bending of plants would be feasible. As a crop protection measure, the practice would probably be more useful during the major crop season when wind-driven rains and high humidities are bound to have detrimental effects on maize culture, especially on pre-harvest grain moisture content and lodging.

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