QPM Resistance and Force

Grain Moisture Content, Kernel Force, and Resistance of Maize

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Introduction

Maize, the world's third largest staple, is the main source of daily nutrition for millions of people in both industrialized and developing countries. Maize is consumed in countless ways; it can be boiled, roasted, or made into tortillas. In some parts of the world, the entire maize ear is used, husk and all, as a means of nourishment. Maize is an important supply for animal feed in both industrialized and developing countries. The maize kernel is used in numerous inedible products as well, such as rubber, plastic, insecticides, and ethanol fuel.

Fifty-eight percent of the land sown to maize is located in developing countries, fifty percent of this land is in the tropics. Even though the area planted to maize is greater in developing countries, nearly two-thirds of the world's maize is produced in industrialized countries, whose climates are almost entirely temperate (Fischer). The USA, China, Mexico, France and Argentina make up the six nations who produce almost 75% of the world's maize supply (The Maize Page). In 1997, the total world production of maize was 589,389,516 metric tons (mt). The United States contributed 238 million mt, nearly 40% of the total (The Maize Page FAOStat).

Developing countries, whose people depend on maize to survive, often do not have the technology and sophisticated processes that are easily accessible in more advanced countries, such as the US and France. This technology includes storage facilities for harvests, both large and small. Small-scale farmers in developing countries, often store their grain in slatted bins, adobe rooms, among the rafters of their dwellings, or even in unprotected fields (CIMMYT).

The storage of maize is a difficult process, especially in developing countries. Maize storage pests, such as *Sitophilus zeamais*, the maize weevil, and *Prostephanus truncatus*, the larger grain borer (LGB), cause tremendous losses in post-harvest stored grains around the world. Both *S. zeamais* and *P. truncatus* are found primarily tropical climates in Africa and Latin America. Both can be difficult to eradicate, without the use of expensive insecticides and storage equipment.

P. truncatus is known for its ability to rapidly reduce large amounts of stored maize kernels into dust. Although the LGB does not begin its infestation in the field, as the maize weevil often does, this pest can destroy an entire storage of grain in 5 months, much quicker than the maize weevil. By nature, the LGB is a forestry pest that adapted to maize quite easy. Since adults of this pest can survive in the wooden frames of highly infested stores, controlling this pest is very difficult (CIMMYT).

LGB is native to Central America and tropical South America, and the extreme southern USA as a major pest of farm-stored maize. In recent years, it has been introduced and become a major pest in most areas in tropical Africa, including Tanzania, Kenya and Brundi.

Quality Protein Maize (QPM), with elevated levels of essential amino acids, has been developed to have a high level of resistance to storage pests, such as the maize weevil and larger grain borer. QPM has also shown to be a high yielding maize, with a nutritional value almost equal that of milk protein. QPM contains the Opaque-2 mutant gene, which causes a change in the protein composition and an increase in the lysine and tryptohan contents. This gives QPM its exceptionally high protein content. Quality Protein Maize has the potential to help reduce malnutrition in developing areas, plus raise livestock much more efficiently.

This experiment tested new varieties of QPM for both their resistance and kernel hardness. The objective was to determine the most resistant newly developed line of QPM.

Materials and Methods

A.) QPM Resistance: The first objective of this study was to find the resistance of new QPM lines to storage pests. Two 150 gram samples were taken from each family of maize samples and measured into glass jars fitted with (40 mesh) brass mesh screens. One was infested with 25 *P. truncatus*, one was infested with 25 *S. zeamais*. After six weeks a preliminary evaluation occurred in which there were a number of variables. In all samples the adult weevils were counted, the damaged and undamaged kernels were counted, and damaged and undamaged kernels were weighed. The excess maize dust was also weighed in the samples containing *P. truncatus*. All infestations were returned to wait for a final evaluation.

Three to five samples from each family were left on the ear and taken to CIMMYT's tropical station in Poza Rica, Mexico. In Poza Rica, the ears were left out for natural infestation. Ears from the same families were left together in plastic mesh bags. Samples were put into a metal cage outdoors and after 6 weeks under went a preliminary evaluation. The ears where evaluated by the percentage of kernels damaged on a five percent scale. All samples were returned and will be evaluated one final time.

B**.) Kernel Force:** Three samples from each family were checked for the toughness of their kernels. 20 kernels from each were sampled. A Force Displacement Meter (Model 921A, Tricor Systems Inc.) equipped with a 20 kg loaded sensor and a probe with a calibrated diameter of .8mm. The probe was lowered at a rate of 1 cm/s until it punctured and broke the kernel.

Results

All samples underwent a preliminary evaluation 6 weeks after infestation. Figure 1 shows the average force and the average damage for *S. zeamais*. Figure 2 shows the average force and the average damage for *P. truncatus*. The results of this evaluation showed the most resistant family of maize to both *P. truncatus* and *S. zeamais* to be family 9901. The most susceptible to *P. truncatus* after 6 weeks was family 9902, and the most susceptible to *S. zeamais* was family 9903.

It is probable that the final evaluation results will show that the maize with the greater kernel force will have less damage, due to a higher resistance. The maize with a lower kernel force will have more damage, due to a lower level of resistance.

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The grain moisture content of maize (GMC), or the humidity of maize in storage, is a factor in resistance of maize to post-harvest pests. It is postulated that kernel harness is an important resistance mechanism to post-harvest pests in maize. The objective of this study was to determine if there is a correlation between the grain moisture content of maize, the force of the maize kernel, and the resistance of maize to storage pests.

Materials and Methods

A.) GMC vs. Kernel Force: The first objective of this experiment was to find the correlation between the humidity, or grain moisture content (GMC), of maize and kernel hardness. Maize samples were tested for the force of their kernels at different levels of humidity. Nine 100-gram samples of a resistant genotype (Pob 84 CUBA/GUAD) and a susceptible genotype (CML 244 x CML 349) were placed in glass jars. In order to bring the samples to varying levels of humidity, a different volume of water was added to each sample (0ml, 1ml, 2ml, 3ml, 4ml, 5ml, 6ml, 8ml, and 10ml respectively). Each sample was then closed with Parafilm airtight elastic (Greenwich, CT) and left at room temperature to equilibrate for five days.

After equilibration, each sample was tested for its grain moisture content and force. A Steinlite Electric Tester (Fred Stein Laboratories, Inc.) was used to test the GMC of each 100-gram sample. Immediately after calculating the humidity, forty kernels of each sample were tested by a Force Displacement Meter (Model 921A, Tricor Systems Inc), equipped with a 20Kg load sensor. A probe (ca. dia. 0.8 mm) attached to the sensor was used to measure the break force of the kernel. The probe was lowered at a rate of 1 cm/s.

B.) Resistance against *S. zeamais* and *P. truncatus*: After determining the relation between the GMC and kernel hardness, samples were made to determine the relation between kernel harness and resistance of maize to both *S. zeamais* and *P. truncatus*. Again, 100-gram samples of resistant (Pop 84 CUBA/GUAD) and susceptible (CML 244 x CML 349) genotypes were measured into glass jars fitted with (40 mesh) brass mesh screens. In order to reach desired grain moisture, a different volume of water was added to each sample. Grain samples were then placed into rooms with different humidity levels to maintain grain moisture at 21 (95%rh), 17 (80%rh), 14 (70%rh), 12.5 (60%rh) and 9.5% (40%rh) at 27ºC. Samples were equilibrated for 5 days prior to infestation.

Three replicates of each treatment were prepared for *P. truncatus, and S. zeamais.* Twenty-five adults for both *S. zeamais* and *P. truncatus* were placed into each jar containing100g of grain. After two months, the samples *containing P. truncatus* will be removed and inspected for percent of grain damage and consumption. After three months, the samples containing *S. zeamais* will be removed and inspected for percent of grain damage and consumption.

Results

GMC and Kernel Force

The first step of this work was to find the correlation between the humidity, or grain moisture content (GMC), of maize and kernel hardness. To find this correlation, maize samples were tested for the force of their kernels at different levels of humidity.

In figure 1 the correlation between the kernel force and humidity is shown for the resistant genotype (Pob 84 CUBA/GUAD). The Pearson Correlation between the force and the humidity is –0.98. As the humidity of the grain increases from about 8% to about 20%, the force of the kernel decreases from about 17kg to about 10kg. This demonstrates that as grain moisture content increases, the toughness of the maize kernel decreases in the resistant genotype

Figure 2 shows the correlation between the kernel force and GMC for the susceptible genotype (CML 244 x CML 349). The Pearson Correlation between the force and GMC is –0.98. As the grain moisture content of the grain increases from about 11% to about 21%, the force of the kernel decreases from about 17 kg to about 8 kg. This is important because it shows that as GMC is increased, the toughness of the kernel is decreased in the susceptible genotype.

Figure 1. Correlation between force and grain moisture content for the resistant genotype Population 84 CUBA/GUAD

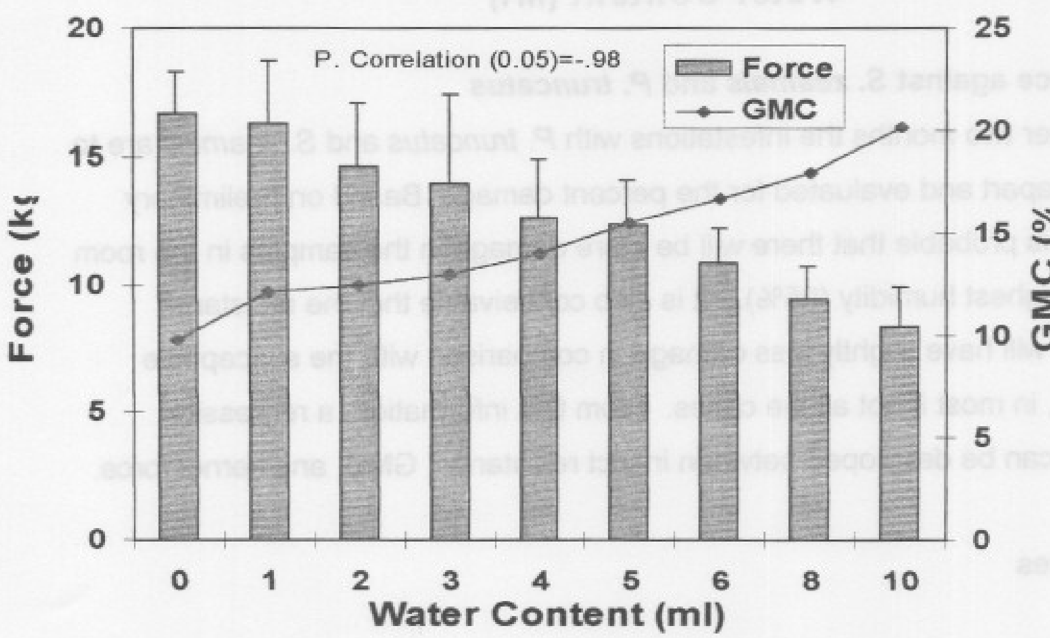
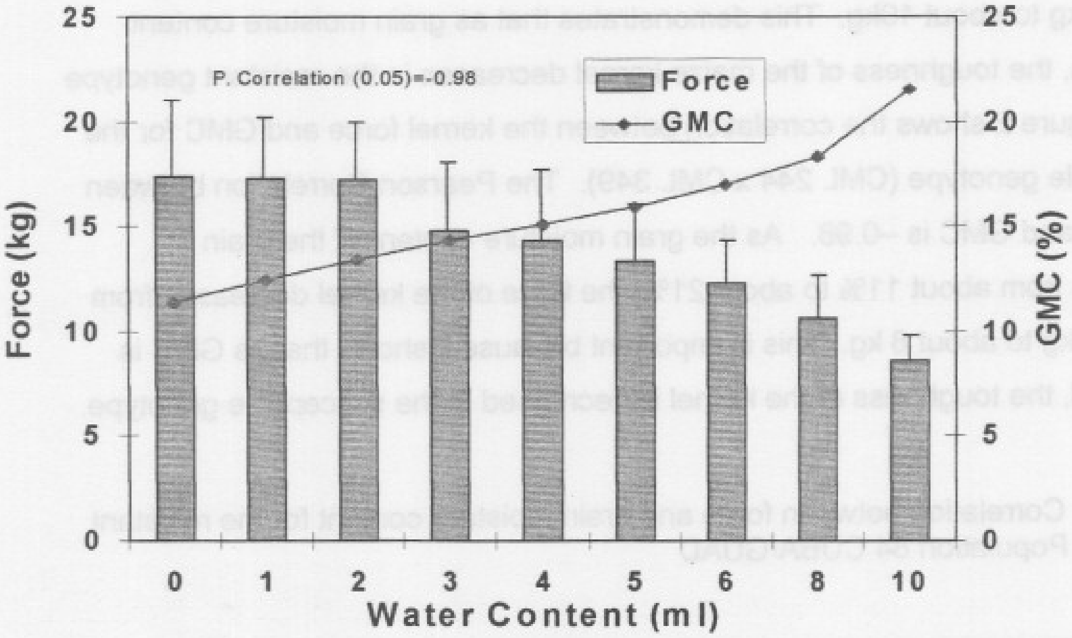


Figure 2. Correlation between force and grain moisture content for the susceptible genotype CML244xCML349



Resistance against *S. zeamais* and *P. truncatus*

After two months the infestations with *P. truncatus* and *S. zeamais* are to be taken apart and evaluated for the percent damage. Based on preliminary results, it is probable that there will be more damage in the samples in the room with the highest humidity (95%). It is also conceivable that the resistant genotype will have slightly less damage in comparison with the susceptible genotype, in most if not all the cases. From this information, a regression equation can be developed between insect resistance, GMC, and kernel force.

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