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Maize and upland rice traits of importance for farmers practicing manual rainfed agriculture in the humid tropics: a Panamanian case-study

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Abstract

The agronomic practices and concerns of poor farmers in comparable ecozones are often similar across countries and regions. Crop ideotypes have helped guide selection for yield under high fertility monoculture conditions in formal breeding programs and could be used to direct breeding for the agricultural conditions of poor farmers. However, the objectives and selection criteria of poor farmers may differ from those of formal breeding programs. This study illustrates a simple survey method for detecting crop traits that are important to poor farmers, and describes results for upland rice and maize ideotypes cropped by swidden agriculturalists in Panama. Our results suggest that formal breeding programs are working on individual crop traits that are important to poor farmers, but they may not be developing varieties that incorporate multiple individual traits (ideotypes), which farmers desire. National breeding programs should play crucial roles in identifying and breeding for regional ideotypes that vary with farming practices and cultural preferences. The field survey techniques reported herein are reproducible, quickly orient breeders towards crop traits that are potentially important to farmers, provide information on the processes underpinning trait importance, and capitalize on decades of farmer experience.

Keywords: Crop traits, ideotype, maize, Panama, poor farmers, rice

Introduction

Participatory breeding programs can help link plant breeding programs more tightly to poor farmers' needs (Sperling et al. 2001). This is important because, globally, 450 million poor farmers support 1.25 billion people (Mazoyer 2001). Many poor farmers practice swidden agriculture (rotating fields between long fallows and short cropping cycles by slashing and burning the biomass that accumulates during fallow periods) (Crutzen and Andreae 1990), but participatory breeding for swidden agriculture has only recently been researched intensively in Central America (Trouche 2005). Identifying crop ideotypes for poor farmers is a first step towards breeding varieties that meet poor farmers' needs (Ceccarelli 1996).

Ideotype breeding is well developed where high-fertility environments (Donald 1968; Mock and Pearce 1975; Peng et al. 1999) and consumer preferences for commercial crops (Van Lieshout 1993) are concerned. Techniques for identifying ideotypes for poor farmers are not as well defined. That poor farmers continue to crop "traditional" rather than "improved" varieties suggests that more extensive ideotype research for poor farmers is required. Although, farmer visual evaluation of varieties is a now common means of obtaining information about trait importance (Sperling et al. 2001) such evaluation is usually done by small groups of farmers appraising a handful of unfamiliar improved varieties at a research station (e.g. Abeyasekera et al. 2002). Recently, field survey techniques have been used to identify traits of importance to poor farmers (Bellon et al. 2005) but the focus has been on a predetermined list of traits, which potentially limits farmers' responses.

Our study was conducted in Panama where rice (*Oryza sativa* L.) and maize (*Zea mays* L.) are the primary staple grain crops (McKay 1990) and swidden agriculture is common (Fischer and Vasseur 2000). Maize is Latin America's most important grain crop (28 million ha), while upland rice accounts for forty percent of rice production in Latin America and the Caribbean, and covers 4.6 million ha (FAO 2001). The present study's objectives were:

1. To implement a simple field survey method for identifying crop traits that are important to poor farmers.
2. To empirically assess the importance of maize and upland rice traits.
3. To compare and contrast important traits with formal breeding program objectives.

Methods

Study area

The study was conducted in the uplands of Herrera province in the Azuero region of the Republic of Panama in December 2004 (Figure 1). Panama is situated in tropical Central America (7^{o}- 9^{o} N and 77° - 83° W), and Herrera province is considered to be the agricultural heartland of the country (Jaen-Suarez 1978). The upland zone where the study was conducted lies between 600 - 1000 m.a.s.l, is comprised of steep broken hills, and includes Holdridge's (1967) tropical moist, premontane wet, and tropical wet forest life zones.

Farmer selection and interview procedures

Access difficulties (poor road infrastructure, lack of telecommunication technology, respondents' highly variable work schedules, etc.) required the use of a targeted small-sample survey. Census data (Contraloría 2001) and consultation with local agricultural extensionists was used to create a sampling frame of towns in the upland zone. The sampling frame consisted of towns with more than 5 houses and that were accessible by 4 x 4 vehicles and/or within three hours walking distance of the nearest vehicularly accessible drop-off point. Towns were then stratified into those belonging to areas practicing swidden agriculture, and areas in transition to permanent agriculture. Five towns were selected at random from each strata (Figure 1). Public meetings were held in selected towns to outline the research process (including participants' rights) and to recruit farmer participants. Farmers' participation in meetings and the study was voluntary.

The study employed a semi-structured interview administered at the respondents' homes. Interviews lasted up to 45 minutes and consisted of two general categories of questions: 1) farmer information (age, education, land use, etc.) and 2) open-ended questions regarding maize and rice traits (listing of positive and negative traits and discussion of the rationale for their importance). Two approaches were used to gather information about maize and rice traits of importance:

1. Farmers, based on their experience, were asked to list the positive and negative traits of the populations of maize and rice they currently cropped.
2. Farmers were asked to list traits they would desire in a new maize or rice variety.

Listing of positive and negative traits for currently cropped populations was conducted prior to listing desirable traits for new varieties.

In the present study the terms; population and variety are defined as follows:

Population: A group of genetically related plants of a particular crop species, which is managed under the same regime (e.g. farmer X's yellow maize).

Variety: A distinct subunit of a crop species that has been defined by plant breeders. The concept of variety is restricted to the products of formal breeding programs but populations may belong either to varieties or "unimproved" materials managed by farmers.

Analyses procedures

Crop traits reported by farmers were assigned to one of seven categories (yield traits, consumption qualities, processing qualities, grain traits, plant traits, stress related traits, and management traits). Percentages were used to illustrate the predominance of specific traits (e.g. Bellon et al. 1998). The percentage of farmers reporting a trait at least once and the percentage of crop populations reported to have the trait were used to assess farmer preference for a trait and trait prevalence within populations, respectively. Analysis of farmer responses was done separately for existing populations and new varieties. Trait importance was assessed based on: trait preference and prevalence within existing populations and trait preference in new varieties.

Results

Sample characteristics

A total of 68 farmers (67 males) who managed separate farms were interviewed. Farmer age ranged from 24 to 80 (mean = 49). Level of formal education ranged from 0-9 years of schooling (mean = 3.9) and 75 percent of farmers were native to their communities (i.e. born there). Selected towns had a combined total adult population (> 18 years of age) of 528 with number of adults per town ranging from 15 – 115 (mean = 53) (Contraloría 2001).

Crop traits

Often, reciprocal positive and negative traits (e.g. drought tolerance = positive, drought susceptibility = negative) indicated a single trait. Reciprocal trait pairs were combined into a single trait when calculating preference percentages. The percentage of populations with the positive or negative version of the trait provided an indication of trait availability. Cases where the negative variant of a trait was equally or more prevalent among maize and upland rice populations than the positive variant indicated a potential trait availability deficiency. In some cases a trait potentially conflicted with another trait (e.g. preference for both tall plants and lodging resistance) indicating cases where potential trade-offs exist between traits.

When farmers report on what they desire in new varieties they are free to mention traits that are not available in their crop populations and can emphasize traits that are important when considering adoption. Defining a short-list of important traits, while based on empirical evidence, also requires subjective judgment. In the present study, maize traits reported by at least 15% of farmers and rice traits reported by at least 20% of farmers were deemed to be important. Traits falling below these thresholds were considered to be important in cases where an availability deficiency or a preference in new varieties was evident. Availability deficiencies are interesting because they indicate a situation where supply is not meeting demand and breeding, including introduction of the desired trait from foreign germplasm, could lead to substantial improvement. However, addressing availability deficiencies while ignoring other important traits would be inappropriate because any new variety must have a competitive trait profile compared to those of currently grown crop populations. Traits that are preferred in new varieties may be of special importance because their presence may make or break adoption.

Upland rice

Of the 68 respondents 50 reported growing rice and provided information on a total of 87 rice populations with each farmer reporting on 1 to 4 populations (mean =1.7). Farmers reported 34 upland rice traits of interest but only 21 traits were mentioned by at least 10% of farmers (Table 1). The percentage of rice populations with positive and negative variants of a trait tended to be high and low, respectively, with a few exceptions (Table 1). Farmers reported 26 different traits to be desirable in new varieties but only 8 traits were mentioned by at least 10% of farmers (Table 2). No new traits (i.e. traits not reported by farmers for existing populations) were reported when listing desirable traits for new varieties. Based on this information 16 important upland rice traits were identified (Table 3).

Maize

Fifty-seven farmers offered information on 75 maize populations with the number of populations per farmer ranging from 1 to 4 (mean = 1.3). Farmers reported 29 maize traits of interest but only 13 traits were mentioned by 10% or more of farmers (Table 1). Farmers reported 25 different traits to be desirable in new varieties but only 6 traits were mentioned by at least ten percent of farmers (Table 2). No new traits (i.e. traits not reported for existing populations) were mentioned for new varieties. However, drought tolerance that was mentioned by less than 10% of farmers for existing populations was the most preferred trait for new varieties. Based on this evidence 12 important maize traits were identified (Table 3).

Discussion

Traits found to be important in this study were searched for in the plant breeding literature to determine whether they were being studied. The literature search queried major databases (e.g. CAB Abstracts, AGRICOLA, Patent Registries, etc.) and journals publishing on international plant breeding (e.g. Euphytica, Crop Science, etc.).

Rice traits of importance to poor farmers

In the present study the important traits constituting an upland rice ideotype (Table 3) were: yield, good panicles (long with many grains), good grain-fill, good-to-eat (soft non-gummy texture), easy threshing and de-hulling, glabrous hulls, earliness, high-tillering capacity, resistance to lodging, pests, shattering, and false smut (*Ustilaginoidea virens* Cooke), and tolerance to drought and infertile soils. Farmers noted that a disadvantage of earliness is increased bird damage, but long awns (> 5cm) and dark hulls can deter birds. With regards to lodging resistance farmers in this study harvest rice by hand and tall rice (95 – 115 cm) is required for ergonomic reasons (i.e. prevent stooping) and makes lodging resistance based on semi-dwarf stature unacceptable. All traits that were reported as desirable in new varieties were also reported to be important traits in existing upland rice populations by 20% or more of farmers (Table 3). Three of these traits: good grain-fill, lodging resistance, and drought resistance have evident availability deficiencies and should receive special attention. Shattering and panicle rot resistance were included as important traits on the basis of potential availability deficiencies.

While some of these traits' importance is clear (e.g. pest resistance) that of others is not. Understanding the processes underlying the importance of these traits is useful when considering their broader applicability. Poor farmers manually process grains and rice populations that are difficult to thresh or de-hull increase labor inputs. However, the importance of easy processing may be temporally unstable because technological change could reduce its importance in the future. An additional problem with easy threshing is there is a potential trade-off with shattering resistance because rice populations that are resistant to shattering are difficult to thresh. Pubescent hulls are disliked because they cause irritation during processing, are believed to be associated with fungal rots, and are difficult to sow in rainy conditions. High-tillering capacity can help compensate for poor germination or low seeding density.

Most of the above traits have been researched in the plant breeding literature. High-yield, long panicles with many grains, and good grain fill are being bred for in rice (Peng et al. 1999). Poor rice farmers are known to have exacting quality preferences

(Virk et al. 2003). Earliness (Fisher et al. 2001) and lodging resistance based on characteristics other than height (Hai et al. 2005) are important in cereal breeding. Awns (Bullard 1988) and dark colored grains (Subramanian et al. 1983) are used to deter birds. Drought resistance and performance in infertile soil are major upland rice breeding objectives (Arraudeau 1995). Improved disease resistance and pest resistance (Bonaman et al. 1992), including false-smut (Biswas 2001), are central rice breeding objectives. High-tillering capacity is an important characteristic of upland rice (Dingkuhn et al. 1999) and glabrous hulls are preferred by rice breeders (Khush et al. 2001). Based on our review of the literature only easy threshing and dehulling do not appear to have been studied extensively.

Maize traits of importance to poor farmers

In the present study the important traits making up a maize ideotype (Table 3) were: yield, good ears (long with many kernels), (weevil (*Sitophilus zeamais* Motschulsky), ear rot, and lodging resistance, fertilizer responsiveness, small kernels, high test-weight, easy-shelling and tolerance to drought and infertile soils. With the exception of drought tolerance all traits reported by farmers as being preferred in new varieties were also reported as preferred traits by at least 15% of farmers for existing maize populations (Table 3). Weevil and ear rot resistance as well as drought tolerance should receive special attention because they were preferred in new varieties but had notable availability deficiencies.

These traits are important to farmers for a number of reasons. Weevil resistance was preferred because maize is stored in open bins without chemical protection and storage losses due to weevils are a problem. Ear rots resistance was preferred because the first maize crop is harvested under rainy conditions that favor fungal disease. Farmers feel that thick husks that tightly cover the end of the cob prevent weevil and fungal damage. Preference for fertilizer responsiveness is an indication that poor farmers, including swidden agriculturalists, are using chemical fertilizers. Small kernels were important because they reduce labor requirements when feeding baby-chicks because milling is not required. Easy-shelling is currently important because maize is hand shelled, daily, for feed and food and easy shelling reduces labor requirements. However, mechanical shellers could reduce the future importance of this trait.

The plant breeding literature has addressed many of the above traits. Yield is a fundamental maize breeding objective but selection has increased kernel weight (larger size) rather than quantity (Duvick 2005). Weevil (Derera et al. 2001) and ear rot (Silva et al. 2007) resistance are being bred for, and selection for robust husk cover is known to prevent insect and fungal damage (Warfield and Davis 1996). Tolerance to drought and low soil fertility (Duvick 2005) are priorities within maize breeding. Fertilizer responsiveness and lodging-resistance are major breeding program objectives (Khush 2001) and test-weight advantages are commonly selected for in maize (e.g. Kramer 2007). To our knowledge, only small kernel size and easy shelling have not been reported on extensively in the plant breeding literature.

Comparing maize and rice traits

Many of the same categories and traits are important for both maize and rice. In particular yield, plant traits, and stress related traits figured prominently for both maize and rice based on a large number of traits highly preferred traits being mentioned for these categories. Individual traits that were common across maize and rice included: yield, easy shelling/threshing, lodging resistance, earliness, pest and rot resistance, tolerance to drought and infertile soils, and fertilizer responsiveness. It is interesting to note that drought tolerance and resistance to rots are simultaneous concerns in the humid tropics. These traits may be important for other crops farmed under similar conditions.

Future considerations for survey methods

Farmers did not report traits for new varieties other than those reported for existing populations. This may be because prior discussion of traits in existing populations focused farmers' attention on these traits but may also result from farmers finding it difficult to value traits they have not experienced first hand. This limitation could be addressed by varying the order of questioning from farmer to farmer and by having farmers report on a list of traits that they may not be aware of. Conversely, farmers may not report important traits that are taken for granted. For instance, without radical changes to harvesting techniques it is unlikely that farmers would accept plants of semi-dwarf stature. Thus, tall stature is important to all farmers but only 10% of farmers reported it to be a positive trait because it is taken for granted (an assumed trait).

For best results these survey techniques should be applied and analyzed by someone with plant breeding knowledge so that reciprocal, trade-off, and assumed traits can be identified. The empirical data these techniques produce must be subjectively interpreted to define a suite of "important" traits (ideotype). If the relative importance of traits is of interest more complex survey and analysis techniques that permit evaluation of limited dependent choice models (Maddala 1983) may be appropriate.

Maize and upland rice ideotypes

The results of the present study suggest that, with the possible exception of processing qualities, formal breeding programs are largely aware of maize and upland rice traits that are important to poor swidden agriculturalists in the humid tropics. This congruence does not necessarily mean that varieties having farmer-desired trait profiles (ideotypes) are being developed. The suites of important traits reported for maize and upland rice in Table 3 constitute ideotypes that should be considered when breeding maize and upland rice for poor farmers in Panama. These ideotypes may be important elsewhere in the humid tropics. The potential broader applicability of our results is evidenced by their agreement with a study in southern Mexico which found: easy shelling, lodging resistance, drought tolerance, ear rot resistance, and pest resistance to be very important for poor farmers growing maize (Bellon et al. 2005).

Conclusions

Farmers have a sophisticated understanding of the traits they desire in crop varieties. Farmer reporting on these traits can help construct ideotypes, but this approach may be limited only to traits that farmers are familiar with. Moreover, some traits may vary in importance because of changing or variable circumstances. National breeding programs should take the lead in applying these survey tools, to identify ideotypes, where contextual variability (e.g. cultural taste preferences, manual processing practices, livestock preferences, etc.) and limited farmer experience with novel traits influence trait importance.

Plant breeding is a broad field and many traits have been reported on in the literature. Formal breeding programs are researching individual traits that are important to farmers in this study. However, it is unclear if study of individual traits has resulted in the packaging of combinations of traits into ideotypes that poor maize and upland rice farmers are willing to adopt. This study outlines maize and upland rice ideotypes for poor farmers in Panama that may be applicable elsewhere in the humid tropics. Moreover, it demonstrates that farmer assessment of currently cultivated populations can be used to uncover ideotypes.

These field survey techniques have limitations. Traits that are unfamiliar to farmers may not be detected and traits of fundamental importance may not be reported because they are considered common knowledge. Furthermore, knowledge of plant breeding is required to interpret results because of the need to identify reciprocal traits and trade-offs. Even with expert guidance these data interpretation is subjective and does not provide information on the relative importance of traits. Despite these limitations these low-cost techniques are reproducible and may be preferable to farmer evaluation of on-station variety trials. This is because these survey techniques quickly orient breeders towards farmers' preferences, provide information on the processes underpinning trait importance, and capitalize on decades of farmer experience.

Figure 1 Study site towns in Herrera province, Panama

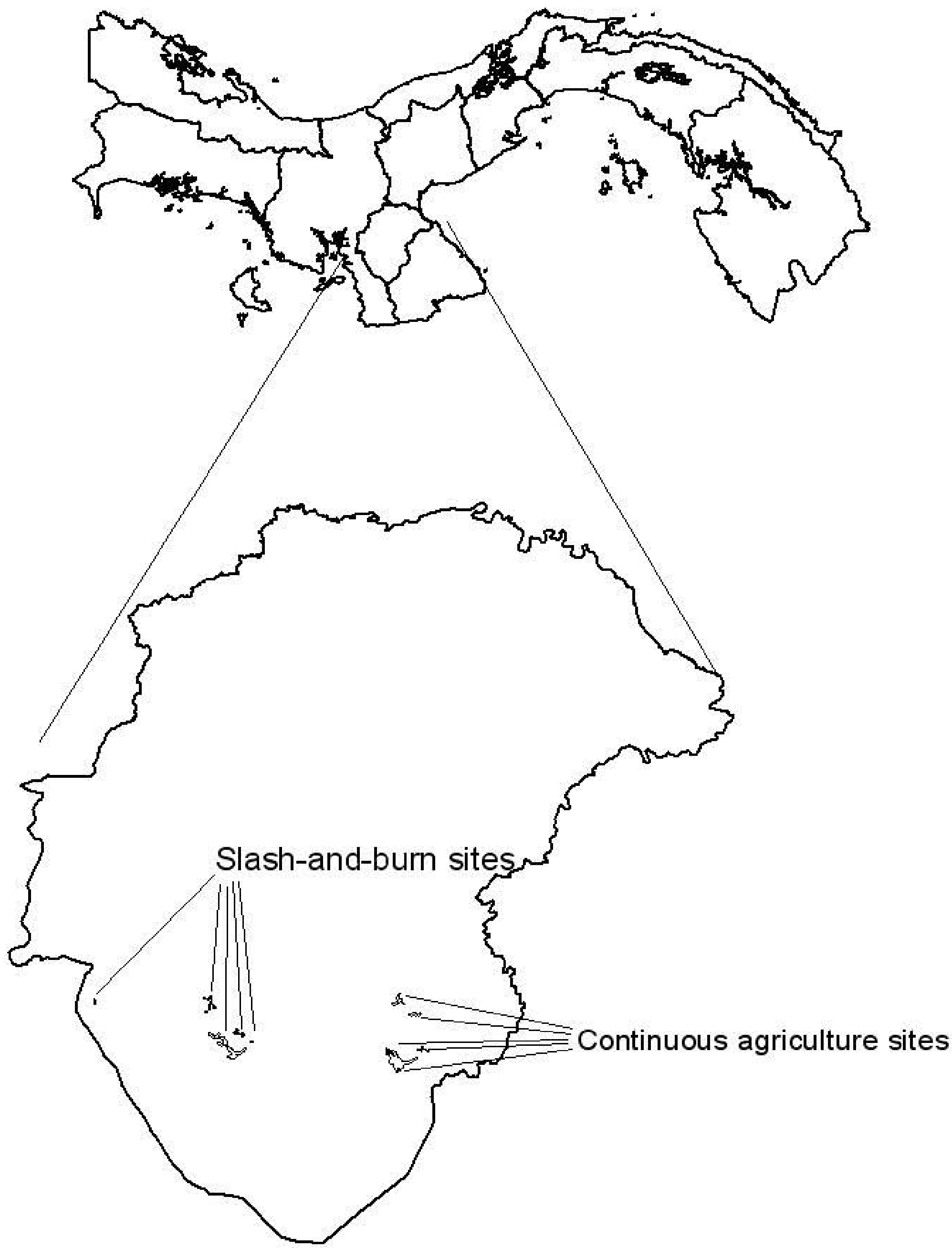

Table 1 Traits belonging to specific categories reported by at least 10% of farmers (%F) for maize and upland rice populations cropped in 2004 in the humid tropics of Panama. The percentage of populations with the positive (%Pos) and negative (%Neg) variants of the trait are given

RICE TRAITS	%F	%Pos	%Neg	MAIZE TRAITS	%F	%Pos	%Neg
YIELD							
Good panicle	42	30	2	Good ear	30	23	1
Good grain fill	38	16	16	Good yield	30	21	3
Yield	30	20	1				
CONSUMPTION QUALITIES							
Good-to-eat	42	26	1	Marketable	14	9	1
Grain expansion	18	14		Good taste	11	8	
PROCESSING QUALITIES							
Easy to thresh	34	21	3	Easy to shell	18	13	3
Easy to hull	30	21					
Shatter resistant	16	3	7				
Dries quickly	12	7					
GRAIN TRAITS							
Dense grain	12	16		Small kernels	26	20	2
				High test-weight	21	13	4
PLANT TRAITS							
Earliness	40	24	2	Resists lodging	19	12	4
Tillering capacity	24	14		Earliness	12	8	1
Resists lodging	20	3	13				
Glabrous hulls	18	6	6				
Tallness	10	6					
STRESS ADAPTATION							
Infertile soil tolerance	30	18	7	Weevil resistance	58	40	15
Resists false smut	26	2	15	Ear rot resistance	44	23	12
Resists drought	20	9	6	Infertile soil tolerance	19	13	1
Resists pests	20	6	6				
Resists panicle rots	16	5	9				
MANAGEMENT							
Herbicide tolerant	14	6	2	Fertilizer responsive	28	12	11
Fertilizer responsive	12	5					

Table 2 Maize and upland rice traits that at least 10% of farmers (%F) reported to be desirable in new varieties, Panama, 2004

Rice traits	%F	Maize traits	%F
Drought tolerance	29	Yield	33
Yield	26	Weevil resistance	28
Good-panicle	21	Ear rot resistance	23
Lodging resistance	19	Good ear	21
Good-to-eat	19	Drought tolerance	16
Good-grain-fill	10	Lodging resistance	14
Infertile soil tolerance	10		
Easy to thresh	10		

Table 3 Important traits reported by farmers for maize and upland rice based on trait preference and desirability in new varieties Panama, 2004

Crop trait	Category	Trait preference (Table1. %F)	Population deficiency (Table 1. %Ppos, %Pneg)	Desirable in new varieties (Table 2. %F)
RICE				
Good panicle	Yield	X		X
Overall yield	Yield	X		X
Good grain-fill	Yield	X	X	X
Earliness	Plant trait	X		
Tillering capacity	Plant trait	X		
Lodging resistance	Plant trait	X	X	X
Glabrous hulls	Plant trait		X	
Easy to thresh	Processing	X		X
Easy to dehull	Processing	X		
Shatter resistant	Processing		X	
Good-to-eat	Consumption	X		X
Infertile soil tolerance	Stress	X		X
False smut resistance	Stress	X	X	
Pest resistance	Stress	X	X	
Drought tolerance	Stress	X	X	X
Panicle rot resistance	Stress		X	
MAIZE				
Overall yield	Yield	X		X
Good ear	Yield	X		X
Small kernels	Grain trait	X		
High test-weight	Grain trait	X		
Lodging resistance	Plant trait	X		X
Easy to shell	Processing	X		
Weevil resistance	Stress	X	X	X
Ear rot resistance	Stress	X	X	X
Infertile soil tolerance	Stress	X		
Drought tolerance	Stress		X	X
Fertilizer responsiveness	Management	X	X	

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