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Review Article

MAIZE AGRONOMIC TRAITS NEEDED IN TROPICAL ZONE

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Abstract: Maize agronomic traits needed by producers and consumers must be taken into account in the breeding programmes. Those traits vary with the target group. In tropical zone, they include earliness, reduced plant and ear heights, resistance to stalk and root lodging, resistance to diseases, weeds and pests, drought tolerance, excellent husk cover, high and stable grain yield, high harvest index and appropriate grain quality. The importance, the inheritance, the heritability and the possibility of improvement of those traits are reviewed. Indications related to the inheritance and the heritability of most of the traits have been reported. But, some of them are much debated. Additive, dominance and epistatic gene effects are involved. Some traits are oligogenic whereas others are polygenic. Heritability values reported are low, moderate or high according to trait, population, environment and computation method. Tropical maize populations can be improved for those traits using appropriate methods.
Keywords: agronomic traits, breeding, gene effects, heritability, maize, tropical zone.

Introduction

Maize (*Zea mays* L) is the second most cultivated cereal crop in the world after wheat (FAO, 2013). It is capable of high levels of production in temperate, subtropical and tropical zones from sea level to high elevation (Gracen, 1986). Its importance in human and animal feeding throughout the world is incontestable.

Maize yields generally less in tropical zone than in temperate zone due notably to climatic constraints (tropical climate is generally less favourable for yield elaboration than temperate climate due to temperature x solar radiation conjunctions (Hainzelin, 1998)), technical constraints (deficiencies of the cultivated varieties, low soil fertility, inappropriate farming and conservation techniques), biological constraints (multiplicity and aggressiveness of biological enemies) and socio-economic constraints. Several high yielding improved varieties have been introduced or created in tropical countries; but, they were not always accepted by producers and consumers due to deficiencies such as poor husk cover, high susceptibility to storage pests and inappropriate grain format and texture. It is therefore,

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essential to take into account the traits needed by producers and consumers in the breeding programmes. These traits vary with the target group; but, some are always indicated in tropical zone. This paper presents the agronomic traits usually needed in maize in tropical zone and reviews their importance, inheritance, heritability and possibility of improvement.

Earliness

Earliness refers to anthesis, silking, maturity or number of leaves. Anthesis corresponds to pollen shedding. Silking is obtained when silks come out of the ears. Grain maturity is obtained when migrations stop. This corresponds to the formation of the black point in hot conditions (Gay, 1984). Milked front and dried husks are also used as maturity indicators.

Anthesis, silking and maturity are usually expressed in days after planting. But, that mode of expression complicates ranging in earliness groups when a population is cultivated in various environmental conditions. The use of thermal units permits to avoid that difficulty (Bonhomme et al., 1994).

Days to anthesis and days to silking are highly correlated (Kim and Hallauer, 1989). Reddy et al. (1986) found that the correlation between days to silking and days to 50% dried husks was high in inbred lines but low in hybrids.

The number of leaves is determined by counting. It is a reliable measure of maize cycle (Salamini, 1985) and is correlated with days to silking (Chase and Nanda, 1967), leaf surface (Muldoon et al., 1984) and plant height (Allen et al., 1973). According to Salamini (1985), the number of leaves depends on two physiological parameters: leaf production rate and panicle initiation time. It is a good indicator of photoperiodism response (Hanway, 1963; Chase and Nanda, 1967; Moss and Hesslop-Harrison, 1968; Hunter et al., 1977 ; Tollenaar and Hunter, 1983 ; Russel and Stuber, 1984). The difference between the number of leaves under short days and the number of leaves under long days has been widely used as photoperiod susceptibility index (Stevenson and Goodman, 1972; Brewbaker, 1981). Complications appeared nevertheless in the use of this index due to its thermodependence (Hanway, 1963; Duncan and Hesketh, 1968; Hesketh et al., 1969; Francis, 1972; Coligado and Brown, 1975). Duncan and Hesketh (1968) reported, for example, that each 10 °C temperature increase induced the appearance of three more leaves. Foliage reduction can increase physiological efficiency in tropical maize (Bjarnason et al., 1985) but within limits.

Earliness is important in tropical zone notably in countries where maize cultivation remains essentially dependent of rains. The use of early varieties can permit to reduce negative effects of drought and obtain two harvests per year in bimodal rainfall regions.

The heritability of days to silking is high (0.59 to 0.94) (Hallauer and Sears, 1972 ; Arha et al., 1990). Hallauer and Sears (1972) found a high heritability (0.56) for number of leaves whereas Claudio-Jobet and Patricio Barriga (1988) reported a low heritability (0.30).

Several authors including Hallauer and Sears (1972), Marandu (1985), Ordas (1988) and Troyer (1990) showed that selection for earliness can be effective in maize. Others such as Efron (1985), Avila (1985), Sauvaire and Sanou (1989), Abadassi et al. (1998), Hainzelin (1998), Abadassi and Hervé (2000) obtained earliness gains through the introgression of exotic germplasm into tropical maize. The reduction of the cycles of tropical maize varieties needed in some cases can, therefore, be obtained by using appropriate methods (bulk population breeding, genealogical selection after hybridization to create parental lines for hybrids, recurrent selection, introgression of exotic material).

Plant architecture

Maize plant architecture is determined by diverse traits including plant and ear heights.

Plant height

The definition of plant height in maize varies with authors. For Jacquot (1970), plant height in maize corresponds to the height of the last node (the insertion of the last leaf). Khristov et al. (1982) consider the height between soil level and the tip of the panicle whereas Beck et al. (1991) take the height between soil level and the starting point of the panicle ramifications. Tropical maize varieties are usually characterized by a great plant height which is, according to Efron and Everett (1969), an indicator of vigor. But, for Pollak et al. (1991), the great height of maize stalks is agronomically deleterious. Low plant heights are needed in tropical breeding programmes to improve lodging resistance or physiological efficiency. Nevertheless, Zuber and Grogan (1961) and Hébert et al. (1990) showed that plant height is lowly or not correlated with root lodging. Working on testcrosses, El-Lakany and Russel (1971) found that plant height was significantly correlated with grain yield. Bjarnason et al. (1985) showed that plant height reduction improved yield by conferring to the varieties the ability to respond to higher plant densities without lodging and maintaining or reducing barreness level. Nevertheless, Fakorede (1979) didn’t notice any correlation between grain yield and plant height in a synthetic population. Plant height is highly correlated with ear height (Kim and Hallauer, 1989; Gyenes-Hegyi et al., 2002) and with vegetative cycle length (Jacquot, 1970).

According to Claudio-Jobet and Patricio Barriga (1988), plant height is moderately heritable. Robinson et al. (1949), Hallauer and Sears (1972), Harville and Josephson (1979), Arha et al. (1990) and Schön et al. (1993) reported relatively high values of heritability (0.43 to 0.70 for Robinson et al. (1949); 0.62 for Hallauer and Sears (1972); 0.63 to 0.89 for Harville and Josephson (1979); 0.53 to 0.89 for Arha et al. (1990); 0.80 for Schön et al. (1993)). But they varied with computation method, material and environment. Harville and Josephson (1979) and Khristov et al. (1982) showed significant dominance effects in the genetic control of plant height in maize whereas Robinson et al. (1949) found little or no dominance effect. Khristov et al. (1982) and Crossa et al. (1987) reported, respectively, significant epistatic effects and predominant additive effects. At least 27 loci influence the quantitative expression of plant height in maize (Sheridan, 1988).

The data found in literature and summarized earlier indicate that plant height in maize is at least moderately heritable. Selection for reduced plant height needed in tropical zone can, therefore, be efficient. It can be realized directly within existing populations if the variability is sufficient or after crosses between populations aiming the increase of variability. The methods will depend on several factors including the type of variety, the initial populations and the available resources.

Ear height

The ear height can be defined as the distance between the soil level and the ear insertion point. If a plant has more than one ear, the height considered is usually the one of the upper ear (Jacquot, 1970; Kim and Hallauer, 1989).

Ear height is highly correlated with plant height in maize (Kim and Hallauer, 1989). Low ear heights are needed in tropical zone to improve root and stalk lodging, physiological efficiency and facilitate harvesting. However, Josephson and Kincer (1977), Helms and Compton (1984) and Hébert et al. (1990) showed that ear height was not significantly correlated with stalk lodging. Josephson and Kincer (1977) generally noted, nevertheless, stalk lodging reductions following ear height reduction and think that one way to reduce stalk lodging should be the reduction of ear height and the increase of the ratio plant height / ear height. The correlation between ear height and yield is as much debated as the one between plant height and yield.

Robinson et al. (1949), Hallauer and Sears (1972), Harville and Josephson (1979), Hallauer and Miranda (1981) and Arha et al. (1990) reported moderate to high values of heritability for ear height. Additive effects of genes predominate in the inheritance of that trait (Ahmad, 1968 ; Harville et al., 1978 ; Harville and Josephson, 1979). Little dominance effects have been noted (Robinson et al., 1949 ; Gardner, 1969 ; Daniel, 1973).

Since ear height is moderately or highly heritable in maize, the reduced ear height needed in tropical zone can be obtained by selection. The methods to be used will be same as the ones indicated for reduced plant height. The high correlation reported for the two heights will facilitate selection for both traits.

Stalk and root quality

Several traits including root lodging and stalk lodging determine root and stalk quality in maize.

Root lodging

Hébert et al. (1990) present root lodging as an abnormal behaviour of the plant which is not enough rooted in wet conditions to resist to the strength exerted by wind on the aerial part. Root lodging should result then from a global disequilibrium between the aerial system and the root system of the plants (Hébert et al., 1992). Root lodging can be also caused, in tropical zone, by pests such as termites. It is generally favoured by farming intensification (nitrogen fertilization, high plant density) (Zuber, 1973; Sauvaire, 1987).

A lot of methods including lodged plants counting in field, resistance to uprooting and visual scoring of rooting have been suggested to appreciate root lodging resistance. The most commonly used method is counting in field; but, it is greatly influenced by environment. Moreover, the definition of lodged plant varies with authors. The Tropical Agronomic Research Institute (IRAT) (IRAT, 1977), for example, suggests to consider as lodged plant a plant inclined at more than 30° from the vertical whereas Sauvaire (1987) suggests a greater referring incline (45°). Melchinger et al. (1986) showed that uprooting resistance did not actually indicate root lodging resistance. Hébert et al. (1990), after working on traits such as the number of levels of roots, the number of roots in some internodes, the growing angle of those roots, the importance of the elongation of the internodes of the base of the stalk, concluded that any trait did not seem to determine, alone, root lodging. Nevertheless, they appreciated the visual scoring (easy to perform, best statistical liaisons with root lodging).

Root lodging can cause important yield losses through its action on plant density and the number of harvested ears. Root lodging heritability may be moderate (about 0.49) (Leford and Russel, 1985; Melchinger et al., 1986) or high (0.69 to 0.83) (Kevern and Hallauer, 1983; Albrecht and Dudley, 1987a). According to Hébert et al. (1990), additive gene effects are predominant in the inheritance of root lodging in maize.

The relatively high heritability of root lodging suggests that selection for resistance to root lodging may be efficient; but complications due to environmental effect may occur.

Stalk lodging

Stalk lodging can be defined as the break of the stalk between the soil level and the main ear insertion node. It is, according to Arnold and Josephson (1975), the result of the complex interaction of several factors. It may be due to a low mechanical strength of the stalk, an unfavourable architecture, insects (stem borers) and diseases damages or the interaction of those factors and others.

The most used method to evaluate stalk lodging is the counting of broken plants in field; but it depends on the environment and is not, therefore, very reliable (Singh, 1971; Arnold and Josephson, 1975). Zuber and Grogan (1961), Zuber and Loesch (1962) and Thompson (1963) showed that the thickness of the barb and the crushing strength of the second and the third internodes were good indicators of stalk lodging. Josephson (1962) suggested to base selection for stalk lodging resistance on the percentage of senescent plants at harvesting when actual stalk lodging index is low. But, for Arnold and Josephson (1975), that method is not completely efficient and give little or no information on the relative importance of the factors responsible for stalk lodging. Foley (1960, 1962), Loesch et al. (1962) showed that stalk lodging was highly correlated with the crushing strength of low internodes and resistance to stalk pathogens.

Stalk lodging can cause significant yield losses (Arnold and Josephson, 1975; Sauvaire, 1987). Its heritability may be low or moderate (0.15 to 0.52) (Singh, 1971; Albrecht and Dudley, 1987b). But, Leford and Russel (1985) found a high heritability (0.75). Additive and non additive effects are both important in the inheritance of stalk lodging ; but, additive effects may predominate (Nigam et al., 1974). Appropriate selection may, therefore, permit to improve stalk lodging resistance of tropical maize populations.

Resistance to enemies

From planting to storage, a lot of groups of biological enemies are known for maize. They include, notably, pathogens, weeds and pests.

Several parasitic diseases affect maize plants in tropical zone. Three of them, rust, tropical blight and streak are among the most important. Rust caused by *Puccinia polysora* appears as small golden round pustules on the leaves. Limb parts densely invaded by pustules turn yellow and dry. That disease attacks particularly oldest leaves at the end of the growing cycle. This limits its incidence on yield (Autrique and Perreaux, 1989). Resistance to the different races of *Puccinia polysora* may be governed by dominant or incompletely dominant genes (Pellegrin and Kohler, 1990). Tropical blight caused by *Exserohilum maydis* is expressed by the presence on the leaves and the foliar sheaths of brown small oval lesions surrounded by a narrow reddish brown band. Maize streak is caused by maize streak virus and is transmitted by insects of the genus *Cicadulina.* It is expressed by the presence on the limb of long chlorotic streaks irregularly interrupted, arranged parallel to the veins or on them. The disease occurs sporadically: damages may be insignificant some years but very important (capable of causing total yield losses) other years (Efron et al., 1989). Resistance to maize streak may be monogenic or polygenic depending on the source of resistance with important additive gene effects (Kim et al., 1982; Efron et al., 1989).

Numerous weeds cause important damages to maize plants in tropical zone notably in competing with them for water, light and nutrients. They include gramineae such as *Imperata cylindrica*, *Panicum maximum* or *Digitaria velutina*, cyperaceae like *Cyperus sp*, Euphorbiaceae like *Euphorbia hirta* and Scrofulariaceae like the parasite *Striga hermontheca*. In Nigeria, for example, yield losses of 65 to 92% have been recorded due to weeds (IITA, 2009).

Pests which cause important damages to maize in tropical zone include termites, stem borers (*Sesamia clamistis*, *Busseola fusca*, *Eldana saccharina*), ladybirds like *Chnootriba neglecta*, the maize weevil (*Sitophilus zeamais*) and the larger grain borer (*Prostephanus truncatus*). According to Clavel and Welcker (1996), damages caused by borers and leaf destroyers caterpillars represent one of the main causes of yield reduction in tropical and subtropical zone**.** Ajala and Saxena (1994) reported yield losses estimations of maize of up to 43% due to stem borers. Pantenius (1988) noted that in general, 80 to 90% of total weight losses in traditional storage systems in Togo were caused by insect pests. For Tefera et al. (2011), the larger grain borer, *Prostephanus truncatus* and the maize weevil, *Sitophilus zeamais* are important pests of stored maize in the tropics, especially where maize is stored on-farm with little control of moisture content and without use of pesticides. *Sitophilus zeamais* plays an important role in the contamination of maize with fungi, especially those that produce toxins (Lamboni and Hell, 2009).

Resistance to enemies is highly needed in tropical zone. The use of resistant varieties is one of the most efficient, economical, practical and ecological enemy control measures.

Drought tolerance

Drought stress is one of the most important abiotic stresses influencing performance of crop plants (Shiri et al., 2010). Maize is a water demanding plant. Under drought stress, maize drought susceptible plants show prolonged anthesis-silking interval, smaller leaf area, thinner stalk, shorter and smaller ears, a decline in plant height and ear position, reduced grain number per ear and grain weight which leads to yield decline (Zhang et al., 2008). Drought is a major factor limiting maize yield in most of the world (Magorokosho et al., 2003). The crop is especially sensitive to moisture stress during flowering (IITA, 1982). Yield losses of up to 75% have been reported (Bolaóos et al., 1993; Logrono and Lothrop, 1996).

The use of maize drought tolerant varieties is essential for crop production, yield improvement and yield stability under drought stress conditions (Khodarahmpour and Hamidi, 2011). Several indices are used to evaluate drought tolerance in maize. Khodarahmpour and Hamidi (2011) studied five of them and found that the mean productivity (MP), the geometric mean productivity (GMP) and the stress tolerance index (STI) were the more accurate criteria for selection of drought tolerant and high yielding inbred lines. Golbashy et al. (2010) reported that harmonic mean (HM), STI and GMP may have the same ability to separate drought sensitive and drought tolerant genotypes. Chen et al. (1996) showed that under drought conditions, leaf rolling rate, stomatal conductance, anthesis-silking interval, number of leaves, plant height, harvest index and leaf angle were associated with drought resistance. According to Williams et al. (1969), the inheritance of drought tolerance in sweet corn follows a pattern of partial to nearly complete dominance and involves at least three gene pairs. Narrow sense heritability estimates reported by Chen et al. (1996) for characters associated with drought resistance in maize were high for number of leaves and leaf angle and low for plant height. Aminu and Izge (2012) estimated broad sense heritability of some traits (anthesis-silking interval, plant height, weight of cobs and grain yield) affected by drought, under drought conditions, and found they were high (60.61% to 67.44%).

Drought tolerant maize varieties can be bred using appropriate methods. This is being done currently by the International Maize and Wheat Improvement Center (CIMMYT) and the International Institute of Tropical Agriculture (IITA) for sub-Saharan Africa. Several varieties have been already released (Abate et al., 2012).

Husk cover

Husk cover is the degree of covering of the ear by the husks. It is usually evaluated visually at maturity. A poor husk cover favours birds and pests damages. A good husk cover (husk going beyond the ear tip and tight husks) confers resistance to maize ears against the maize weevil (*Sitophylus zeamais*) in field (Demissie et al., 2008). Several tropical maize varieties possess an intermediate or poor husk cover and are, therefore, less accepted by producers. Abadassi and Hervé (2000) showed that recurrent selection can permit to improve populations for that trait.

Grain yield

Grain yield is a complex trait. It is the product of several components including the number of ears per plant, the number of grains per ear and the mean grain weight. Its heritability is low (0.09 to 0.38) (Robinson et al., 1949; Hallauer and Miranda, 1981; Ordas et al., 1987; Claudio-Jobet and Patricio Barriga, 1988).

The mean number of ears per plant or prolificacy is the ratio of the number of harvested ears to the number of plants recorded at harvest. It is highly and positively correlated with grain yield (Robinson et al., 1951; Goodman, 1965; Lonnquist et al., 1966; Monteagudo, 1971) and highly heritable (Leng, 1954, 1963; Laible and Dirks, 1968; Monteagudo, 1971). Low values of heritability have been, nevertheless, reported by Robinson et al. (1949), Claudio-Jobet and Patricio Barriga (1988) and Brun and Dudley (1989). Gardner et al. (1953), Leng (1954), Lindsey et al. (1962) and Monteagudo (1971) reported that partial dominance and predominant additive genetic effects are usually noted in the inheritance of prolificacy. Laible and Dirks (1968) showed, nevertheless, complete dominance and superdominance effects. The number of grains per ear can be obtained by direct counting or by multiplying the number of rows per ear and the number of grains per row. It is positively correlated with grain yield (Agbaje et al., 2000) as is the number of rows per ear (Fakorede, 1979; Agbaje et al., 2000). Its heritability is high (0.57 to 1) (Hallauer and Miranda, 1981; Ordas et al., 1987), low or moderate (0.16 to 0.53) (Arha et al., 1990) depending on the material and the environment.

The mean grain weight is determined after counting and weighing of a number of grains. El-Lakany and Russel (1971) and Golam et al. (2011) showed that mean grain weight was not positively correlated with grain yield. The heritability of grain weight may be moderate (Hallauer and Miranda, 1981) or high (Brun and Dudley, 1989).

The three yield components described earlier can be highly heritable. Therefore, selection for them can be efficient. Grain yield is lowly heritable. But it can be increased by recurrent selection (Gardner, 1961, 1969; Johnson, 1963; Lonnquist, 196 ; Arboledo-Rivera and Compton, 1974; Johnson et al., 1986; Paliwal et al., 2002). Hainzelin (1998) summarized varietal traits that contribute to maximum yield. They are notably : homogeneous and synchronized cover, improved behaviour at high densities (improved harvest index, architecture more adapted to high densities (less dense and more erect upper leaves, reduced panicle), better plant tenure (root and stalk lodging resistance), better equilibrium between the cycle phases (shorter vegetative phase, longer grain filling phase, more rapid drying) and better stress resistance.

Harvest index

Harvest index is the ratio of the grain yield to the total biomass yield (Donald, 1962). It is a potential criterion for indirect selection to increase grain yield in cereals (Rosielle and Frey, 1975; Nass, 1980). Sharma et al. (1987) found, nevertheless, that harvest index was not significantly correlated with grain yield in wheat. In maize, harvest index is negatively correlated with plant density (Begna et al., 2000).

In temperate zone, harvest index, in maize, is highly heritable except under severe stress. In tropical maize, the magnitude of harvest index is not highly heritable varying inconsistently with season, management and environment (Hay and Gilbert, 2001).

In tropical zone, maize is essentially cultivated for its grains. Tropical maize varieties have, generally, a low harvest index (about 0.35) (Yamaguchi, 1974; Goldsworthy et al., 1974; Bjarnason et al., 1985). Varieties with high harvest index are then needed in tropical zone to improve physiological efficiency.

Selection for reduced plant height, foliage and panicle can increase harvest index (Bjarnason et al., 1985). Introgression of appropriate temperate germplasm can also improve the harvest index of tropical maize populations (Avila, 1985; Efron, 1985; Abadassi and Hervé, 2000).

Grain quality

Grain quality usually includes traits such as colour, format, texture, aptitude to transformations and protein, amino acids (notably the essential ones such as lysine and tryptophan), oil and starch contents.

Maize grain colour varies greatly with variety. Among the common colours known appear: yellow, white, purple, red and orange. Carotenoids pigments are responsible for endosperm colour. Maize grain contains several types of carotenoids (pro-vitamin A) that are synthesized into soluble-fat vitamin A in mammals (Egesel et al., 2003). White grain has minimum levels of carotenoids whereas yellow grain can have appreciable levels (Chandler et al., 2013). Two classes of carotenoid pigments in maize are carotenes and xanthophylls which impart yellow or orange colour to endosperm. Yellow endosperm maize colour is partly controlled by the yellow endosperm-1 (Y1) locus. Dominant Y1 allele results in yellow endosperm pigment and recessive y1 allele results in a lack of endosperm colour (Egesel et al, 2003). Chandler et al. (2013) showed that visually scored kernel colour had a moderate heritability and identified five common quantitative trait loci (QTL) and six rare QTL for intensity of orange colour.

The texture of maize grain can be dent, flint or intermediate. It is a fundamental characteristic for the industry as well as for grain producers and processors (Pereira et al., 2008). Grain texture influences grain shipping and processing characteristics, susceptibility to insects and flour cooking properties. It is associated with the levels of protein and soluble sugar, starch level, endosperm cell number, endosperm cell length and starch granule diameter (Zhang et al., 2011). Hohls et al. (1996) reported that kernel vitreousness and kernel hardness were determined by partially dominant genes. Grain size varies with variety and may be controlled by several genes (Motto et al., 2011).

The great economical and nutritional value of maize grain is mainly due to its high starch content (approximately 75% of the mature seed weight) (Motto et al., 2011). Most of the starch is contained in the endosperm. Several genes are involved in the control of starch content in maize (Motto et al., 2011; Yang et al., 2013). Yang et al. (2013) obtained high broad sense heritability estimates for that trait in two populations.

Maize grain contains 6 to 15% of protein (mainly zeins) depending on the variety. That protein is generally poor due to low contents of lysine and tryptophan, two essential amino acids for human and animal nutrition (IITA, 1982). The protein content is negatively correlated with starch content and its genetic control involves tightly-linked QTL, pleitropic QTL and QTL having opposite effects (Li et al., 2009).

Maize is among the richest cereals in oil. It contains 3 to 4% of oil located in the germ layer and the endosperm) (IITA, 1982). Maize oil is of high quality for human nutrition owing to its low content of saturated fatty acids such as palmitic acid and stearic acid and its relatively high content of polyunsaturated fatty acids like linoleic acid (IITA, 1982; Motto et al., 2011). Oil content is positively correlated with protein and lysine contents and negatively correlated with starch content (Song and Chen, 2004). Multiple QTL are involved in kernel oil content in maize (Laurie et al., 2004; Yang et al.,2012). Moderate to high values of heritability have been reported for that trait (Rosulj et al.. 2002; Song and Chen, 2004).

Genetics usually exert the largest effect on maize grain quality; but, agronomic practices are also important (Mason and D'croz-Mason, 2002). The grain quality needed in tropical zone depends on the destination of the production. Three main destinations are known: human consumption, animal feeding and industries. For production destined to human consumption for example, the preferences vary with the consumers. A lot of African consumers prefer white grains although they are poor in pro-vitamin A. That contributes to vitamin A deficiency especially where maize is a staple food. The consumers of Benin prefer grains which are not only white but also small, easy to grind and suitable for usual food transformations. Selection for grain quality may be efficient; but it leads, sometimes, to negative effects. Rosulj et al. (2002) obtained such results: oil content increase but grain yield decrease. In the same way, Song and Chen (2004) got, after a long term selection for oil content in five maize populations, significant oil content increase but starch content decrease. To be satisfactory, selection for grain quality should concern a few traits highly heritable and positively correlated. Those traits should not be negatively correlated with other key agronomic traits.

Conclusion

Agronomic traits needed in maize in tropical zone vary with the target group. Nevertheless, some are always indicated. They include : earliness, appropriate plant architecture, good stalk and root quality (lodging resistance particularly), resistance to the enemies (pathogens, weeds, pests), drought tolerance, good husk cover, high and stable grain yield, high harvest index and appropriate grain quality. Indications related to the inheritance and the heritability of most of the traits have been reported. But, some of them are much debated. Tropical maize populations can be improved for those traits using appropriate methods.

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