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Zea mays L.: REVIEW OF MORPHOLOGY OF TASSEL COMPONENTS THAT CAN INFLUENCE THE AMOUNT OF POLLEN

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Abstract

Pollination is essential for hybrid seed production in maize, relying heavily on the pollen output of inbred male plants. Effective pollination ensures kernel development, genetic purity, and high-quality hybrid seeds. Tassel morphology—including traits like weight, branch count, and Tassel Area Index - plays a key role in pollen production. Breeding programs must optimize these traits to balance pollen availability with minimal negative effects, such as leaf shading. Integrating genetic and phenotypic assessments can enhance pollination efficiency and hybrid reliability. This approach supports yield stability and resilience under diverse environmental conditions, contributing to sustainable maize production.

Key words: *pollen. Zea mays L., tassel morphology, pollination.*

INTRODUCTION

Maize (*Zea mays* L.) is recognized as the most widely cultivated cereal globally, with the United States of America, China, and Brazil leading production rankings (FAO, 2023). In 2023, the global area dedicated to maize cultivation was estimated to be between 200 and 210 million hectares. This crop's widespread cultivation is attributed to its remarkable productivity and versatility. For example, maize serves as a critical component in diverse industries, including animal feed, staple foods such as flours, hominy, oil, and bread, and even in specialized sectors like brewing, pharmaceuticals, and mining (Strazzi, 2015). In Europe, approximately 16 to 18 million hectares were sown with maize during the 2023 season. This figure varied slightly due to factors such as weather conditions, market dynamics, and crop rotation practices. Among the leading European maize producers are France, Ukraine, Romania, and Hungary, with Romania maintaining a dominant position in maize cultivation. Recent data highlights that Romania consistently cultivates around 2.5 million hectares annually, making it the European Union's largest producer in terms of cultivated area (FAO, 2023). This leadership can be attributed to Romania's favorable climatic and soil conditions, particularly in its southern and eastern regions. From a personal perspective, Romania's strategic emphasis on maize cultivation reflects its broader agricultural strengths and adaptability. These favorable conditions could position the country as a potential hub for innovation in maize-based product development, which could enhance its competitiveness in the global market. The multiple applications of maize in food production, industrial uses, and beyond further underscore its significance in ensuring both economic stability and food security.

Maize holds substantial economic significance, and breeding programs are vital for developing genotypes with agronomic traits that align with producer needs and consumer market expectations. Modern maize genotypes have been optimized for traits such as reduced plant and ear heights, more upright leaf angles, smaller tassels (fewer branches and lower mass), shorter intervals between tasselling and silking, decreased grain protein content, and increased yield potential (Duvick, 2005).

One of the most critical stages in maize development is flowering, which directly impacts yield. This phase typically spans 5 to 14 days (Ogden et al., 1969) and begins with pollen release from the tassel, followed shortly by silk emergence. Remarkably, each maize plant produces approximately 25 million pollen grains, ensuring a robust reproductive capacity with around 25,000 pollen grains available per silk (Kiesselbach et al., 1949). This interplay between tassel and silk dynamics underscores the complexity of maize reproductive biology.

Tassel size plays a pivotal role in yield determination. Larger tassels can reduce grain yield by shading upper leaves, thereby diminishing photosynthetic efficiency, and by acting as sinks for photo assimilates (Edwards, 2011; Souza et al., 2015). However, in environments with stress factors such as limited water availability, larger tassels may become advantageous by ensuring sufficient pollen production for fertilization (Parvez, 2007). Breeding programs have thus focused on selecting smaller tassels to reduce shading effects, enhance photosynthetic performance, and allow higher planting densities. While this strategy improves yield potential, it has inadvertently reduced pollen production (Duvick & Cassmann, 1999). Consequently, understanding factors influencing pollen production and germination has become a priority to support breeding programs and hybrid seed production. Tassel size, defined by traits such as branch number, branch length, spikelet count, and tassel area index, exhibits a complex relationship with yield. Specifically, a negative correlation with grain yield is often observed, alongside a positive correlation with pollen production (Fonseca et al., 2003). This duality poses challenges in breeding programs aimed at optimizing tassel traits.

The reduction of tassel size has been instrumental in improving planting efficiency and yield under optimal conditions, there is a growing need to develop adaptive strategies for stress-prone environments. Incorporating genetic diversity and exploring innovative breeding techniques could balance the trade-offs between pollen production and yield. This balance is critical to sustaining productivity as environmental conditions continue to fluctuate due to climate change.

TASSEL CHARACTERISTICS AND THEIR ROLE IN MAIZE POLLEN PRODUCTION

This scientific publication provides an in-depth analysis of tassel characteristics—such as tassel weight, stalk diameter, number of primary branches, total branch length, tassel length from lower and upper branches, and Tassel Area Index - and their influence on pollen production in maize inbred plants. The study examines the morphology of tassel components under conditions of heat stress and evaluates how these changes impact pollen production. Pollination is a critical process in the growth and development of higher plants and is particularly sensitive to unfavourable environmental conditions (Ali et al., 2018). Among these, heat stress is a prominent environmental challenge that significantly affects the physiological and phenotypic traits of reproductive organs, as well as the pollination process (Hatfield and Prueger, 2015; Gabaldón-Leal et al., 2016). Even short episodes of heat stress during the crucial flowering stage can result in substantial yield losses (Tian et al., 2018; Wang et al., 2022).

This research underscores the importance of understanding the intricate relationships between tassel morphology and pollen production under stress conditions. By identifying key traits associated with resilience, the study aims to contribute to breeding strategies that enhance maize productivity in the face of climate variability.

GENETIC AND MORPHOLOGICAL INTERACTIONS OF TASSEL TRAITS: IMPLICATIONS FOR POLLEN PRODUCTION AND YIELD IN MAIZE

In maize breeding, increasing emphasis is placed on selecting traits that maximize yield by optimizing energy conversion processes. Key traits include plant height, ear height, leaf number, and leaf area. Additionally, tassel characteristics play a significant role in influencing plant performance and productivity (Body et al., 2008).

During the development of inbred lines, tassels often display reduced development, diminished pollen production, and, in extreme cases, male sterility. These effects, attributed to inbreeding, lead to significant variability in pollen competitiveness among inbred lines (Sari-Gorla et al., 1975) and F_1 hybrids (Pfahler, 1967). Excessive selection pressure, compounded by the genetic background of the lines, can detrimentally impact both male and female reproductive traits in maize. This highlights a critical challenge in breeding programs: maintaining a balance between inbreeding to fix desirable traits and avoiding the associated negative effects on fertility. From a practical standpoint, addressing this issue requires a multifaceted approach. Breeding strategies must incorporate a deeper understanding of genetic interactions that drive these reproductive changes. The focus should shift from solely maximizing yield potential to maintaining a robust reproductive framework, particularly under the stress conditions often encountered in nurseries and seed production environments. This balance is essential not only for the development of high-performing hybrids but also for ensuring the sustainability of breeding programs over time (Vidal-Martínez et al., 2001). Therefore, integrating genomic tools and phenotypic assessments could help breeders identify genotypes with improved resilience to inbreeding depression. Additionally, maintaining genetic diversity within breeding populations could serve as a buffer against the adverse effects of excessive inbreeding, ensuring that the development of new inbred lines supports both productivity and reproductive success.

The tassel, the male inflorescence of maize, is a commonly studied aspect of the plant. Maize, being monoecious and heteroecious, depends significantly on the development of its male flowers for reproductive success (Bocz, 1992). The morphology of the tassel, especially traits affecting pollen production, plays a vital role in seed production and the selection of hybrids. Numerous studies have investigated the connection between pollen production and tassel characteristics (Vidal-Martínez et al., 2001; 2004; Fonseca et al., 2003; Rácz et al., 2006). Additionally, the genetic basis of tassel traits has been explored. Mock and Schuetz (1974) found that the number of tassel branches is a quantitative trait with high heritability. Geraldi et al. (1978) also provided heritability estimates, reporting 86.1% for tassel weight, 45.8% for tassel branch number, and 28.8% for tassel length. However, the inheritance mechanisms of these traits remain incompletely understood (Berke and Rocheford, 1999).

Research has consistently shown that an increase in the number of tassel branches negatively impacts grain yield (Geraldi et al., 1978; 1985; Vidal-Martínez et al., 2001; Gyenesné Hegyi et al., 2001; Hegyi, 2003). This is likely because the plant's resources are diverted toward tassel development, reducing the energy available for grain formation. Similarly, tassel weight is negatively correlated with grain yield but positively correlated with the number of branches (Geraldi et al., 1985). These findings suggest that selecting for maize genetics with fewer tassel branches and smaller tassels could indirectly improve kernel yield. This improvement would result from reduced energy expenditure on tassel development and minimized shading effects on the upper leaves, which are critical for photosynthesis (Lambert and Johnson, 1977). However, it is important to note that smaller tassels in male parental inbred lines may create challenges for F_1 seed production and the maintenance of male lines. This is because smaller tassels produce less pollen and have reduced dispersal efficiency (Wych, 1988). This dilemma highlights the importance of finding a balance between tassel size and pollination efficiency in breeding programs.

The number of tassel branches is a key factor in pollen production (Vidal-Martínez et al., 2001a), and a higher number of branches tends to dominate over fewer branches (Mock and Schuetz, 1974; Hegyi, 2003). Hegyi (2003) observed an inverse relationship between the productivity of individual lines and the number of tassel branches. This suggests that while a higher number of branches may increase pollen production, it can simultaneously reduce grain yield. Analyses using Pearson's correlation coefficient to examine the relationships between tassel components and quantitative traits indicate that these traits interact both directly and indirectly (Body et al., 2008). The presence of moderate to strong correlations, supported by high reliability, underscores the potential for these traits to influence one another indirectly. These observations provide valuable insights for breeding programs, suggesting that optimizing tassel traits could have beneficial effects on other plant characteristics.

From my perspective, these findings should encourage researchers and plant breeders to adopt a more holistic approach to maize improvement. For example, strategies could be explored to minimize the negative effects of large tassels, such as selecting for more compact tassels or optimizing their positioning on the plant. At the same time, it is essential to maintain an adequate level of pollen production to ensure successful pollination and seed formation. Additionally, I believe that integrating modern technologies, such as imaging analysis and 3D modelling of tassels, could provide a deeper understanding of the relationships between tassel morphology and crop performance. These tools could facilitate the identification of innovative solutions for tassel optimization, contributing to improved yield and sustainability in maize cultivation.

Morphological traits and grain yield components develop sequentially during plant growth. These traits are quantitative, governed by multiple genes (Ledent, 1984), and often show a genetic correlation with grain yield, exhibiting high heritability (Gallais, 1984).

CONCLUSIONS

Tassel stalk diameter displayed a moderate positive correlation with tassel length measured from the lower side branch, while its correlation with tassel length from the upper side branch was weak but statistically significant (P=0.01%). However, its associations with other traits were negligible. Unlike tassel stalk diameter, most tassel characteristics exhibited medium to high heritability values, as noted by Upadyayula et al. (2006).

The Tassel Area Index (TAI) exhibited a significant negative correlation with plant height, crop yield, and thousand kernel weight (P=0.01%). A moderate negative correlation was also noted with ear height and leaf area index (Body et al., 2008). On the other hand, multiple studies have identified strong positive correlations between leaf area index, plant height, and crop yield (Zsubori et al., 2002; El Hallof and Sárvári, 2006; Jakab, 2003). These opposing relationships underscore the dual influence of tassel morphology, as its shading effect on leaf area contributes to the negative associations with yield-related traits. These findings are consistent with earlier research by Lambert and Johnson (1977) and further validate the relevance of TAI in plant breeding initiatives.

In my view, TAI serves as a critical indicator for optimizing maize breeding strategies. As Fonseca et al. (2003) suggested, TAI can predict the pollen-producing potential of maize genotypes, underscoring its relevance in parent selection for seed production. However, our findings show a negative correlation between TAI and yield-related traits, indicating that a balance must be struck between sufficient pollen production and minimizing the shading effects of larger tassels. Interestingly, a weak but positive correlation was observed between TAI and test weight, suggesting that further exploration of this relationship could refine selection criteria for high-performing genotypes.

Thousand kernel weight showed a moderate negative correlation with test weight at a high reliability level (Body et al., 2008). This result diverges from the findings of Li et al. (2007), who reported significant positive correlations, and from earlier studies by Pomeranz et al. (1986) and Dorsey-Reading et al. (1991), which found weak or no significant correlations between these parameters. These discrepancies underline the complexity of genetic and environmental factors influencing grain traits and emphasize the need for further investigations into these relationships.

The importance of tassel components in maize breeding is expected to increase significantly in the near future. Analysing correlations among tassel traits offers crucial information that can be effectively utilized in selection strategies. Notably, the tassel area index (TAI), represents the combined influence of various tassel components, presents a valuable approach for targeting traits with relatively low heritability.

From a practical perspective, more emphasis should be placed on research into tassel morphology, not only in seed multiplication programs but also in conventional maize production systems. Such efforts could enhance efficiency and yield outcomes by enabling breeders to identify and select genotypes with optimal tassel characteristics for different production environments. The integration of these findings into modern breeding programs could lead to more resilient and productive maize hybrids, ensuring greater adaptability to changing climatic and agricultural conditions.

REFERENCES

Anda, A., Tóbiás, F. (1999). Comparative study for the estimation of single leaf area in maize and for the verification of two different leaf area meters. *Növénytermelés*, 48:55–67.

Berke, G. T., Rocheford, R. T. (1999). Quantitative trait loci for tassel traits in maize. *Crop Science*, 39:1439–1443.

Bocz, E. (1992). Szántóföldi növénytermesztés. (Crop production). *Mezőgazda Kiadó*, Budapest.

Bódi, Z., Pepó, P., Kovács, A. (2008). Morphology of tassel components and their relationship to some quantitative features in maize. *Cereal Res. Commun.*, 36:353–360.

Carvalho, I. R., et al. (2017). Components of variance and interrelation of important traits for maize (*Zea mays*) breeding. *Australian Journal of Crop Science*, 11:982–988.

Duvick, D. (2005). The contribution of breeding to yield advances in maize (*Zea mays* L.). *Advances in Agronomy*, 86:83–145.

Duvick, D. N., Cassmann, K. G. (1999). Post-green revolution trends in yield potential of temperate maize in the North-Central United States. *Crop Sci.*, 39.

Edwards, J. (2011). Changes in plant morphology in response to recurrent selection in the Iowa stiff stalk synthetic maize population. *Crop Science*, 51:2352–2361.

Fonseca, A. E., Westgate, M. E., Grass, L., Dornbos, D. L. (2003). Tassel morphology as an indicator of potential pollen production in maize. *Crop Manag.*, 2:1–15.

Gallais, A. (1984). Use of indirect selection in plant breeding. In: *Efficiency in Plant Breeding*. Lange W., Zeven, A. C., Hogenboom, N. G. (eds). Pudoc, Wageningen, The Netherlands. pp. 45–60.

Garnier, P., Maurice, S., Olivier, I. (1993). Costly pollen in maize. *Evolution*, 47(3):946–949.

Geraldi, I. O., Miranda Filho, J. B., Vencovsky, R. (1985). Estimates of genetic parameters for tassel characters in maize (*Zea mays* L.) and breeding perspectives. *Maydica*, 30:1–14.

Geraldi, I. O., Miranda-Filho, J. B., Vencovsky, R. (1978). Prospects of breeding maize (*Zea mays* L.) with reference to tassel characters. *Abstracts, 30th Annual Reunion. Brazilian Society for Scientific Progress*, 30:533–534.

Gyenesné Hegyi, Zs., Kizmus, L., Nagy, E., Marton, L. Cs. (2001). Kukorica (*Zea mays* L.) címerágak számának és az egyedi produkciónak vizsgálata eltérő ökológiai körülmények között.

Hatfield, J. L., Prueger, J. H. (2015). Temperature extremes: effect on plant growth and development. *Weather. Clim. Extrem.*, 10:4–10. https://doi.org/10.1016/j.wace.2015.08.001

Hegyi, Zs. (2003). A termőhely és a tőszám hatása különböző rokonsági körökbe tartozó beltenyésztett kukorica törzsek și hibridjeik tulajdonságaira. *Doktori Ph.D. értekezés*.

Hidvégi, Sz., Rácz, F., Szöllősi, G. (2005). Relationship between the viability of maize-pollen and the fertilization. *Cereal Research Communications*, 33:121–125.

Hidvégi, Sz., Rácz, F., Tóth, Z., Nándori, S. (2006). Relationship between the viability of maize-pollen and quantity of crop. *Cereal Research Communications*, 34(1):477–480.

Jakab, P. (2003). The importance of nutrient supply in the hybrid-specific corn production. *PhD thesis*, Debrecen.

Jarosz, N., Loubet, B., Durand, B., McCartney, H. A., Foueillassar, X., Huber, L. (2003). Field measurement of airborne concentration and deposition rate of maize pollen (*Zea mays* L.) downwind of an experimental field plot. *Agric. For. Meteorol.*, 119:37–51.

Ledent, J. F. (1984). Morphological characters: A physiological analysis. In: *Efficiency in Plant Breeding*. Lange W., Zeven, A. C., Hogenboom, N. G. (eds). Pudoc, Wageningen, The Netherlands. pp. 63–71.

Li, Z., Shu-ting, D., Cun-hui, L., Kong-jun, W., Ji-wang, Z., Peng, L. (2007). Correlation analysis on maize test weight, yield and quality. *Scientia Agricultura Sinica*, 40:405–411.

Mock, J. J., Schuetz, H. S. (1974). Inheritance of tassel branch number in maize. *Crop Science*, 14:885–888.

Ogden, E. C., Hayes, J. V., Raynor, G. S. (1969). Diurnal patterns of pollen emission in Ambrosia, Phleum, Zea and Ricinus. *Am. J. Bot.*, 56:16–21.

Ottaviano, E., Sari-Gorla, M., Villa, M. (1988). Pollen competitive ability in maize: within population variability and response to selection. *Theor. Appl. Genet.*, 76:601–608.

Parvez, A. S. (2007). Genetic analysis of tassel and ear characters in maize (*Zea mays* L.) using triple test cross. *Asian Journal of Plant Sciences*, 6:881–883.

Pfahler, P. L. (1967). Fertilization ability of maize pollen grains. 2. Pollen genotype, female sporophyte, and pollen storage interactions. *Genetics*, 57:513–521.

Ricci, B., Monod, H., Guérin, D., Messéan, A., Maton, C., Balique, B., Angevin, F. (2012). Predicting maize pollen production using tassel morphological characteristics. *Field Crop Res.*, 136:107–115.

Schoper, J. B., Lambert, R. J., Vasilas, B. L. (1986). Maize pollen viability and ear receptivity under water and high temperature stress. *Crop Science*, 26:1029–1033.

Schoper, J. B., Lambert, R. J., Vasilas, B. L. (1987). Pollen viability, pollen shedding, and combining ability for tassel heat tolerance in maize. *Crop Science*, 27:27–31.

Strazzi, S. (2015). Derivados do milho são usados em mais de 150 diferentes produtos industriais. *Visão Agrícola*, 13:146–150.

Tian, B., Zhu, J., Nie, Y., Xu, C., Meng, Q., Wang, P. (2018). Mitigating heat and chilling stress by adjusting the sowing date of maize in the North China Plain. *J. Agro. Crop Sci.*, 205:77–87. https://doi.org/10.1111/jac.12299

Upadyayula, N., Wasson, J., Bohn, O. M., Rocheford, R. T. (2006). Quantitative trait loci analysis of phenotypic traits and principal components of maize tassel inflorescence architecture. *Theoretical Applied Genetics*, 113:1395–1407.

Wang, T., Wang, F., Song, H., Zhou, S., Ru, X., Zhang, H. (2022). Maize yield reduction and economic losses caused by ground-level ozone pollution. *J. Environ. Manage.*, 324.

Wych, R. D. (1988). Production of hybrid seed corn. In: *Corn and Corn Improvement*. Sprague, G. F., Dudley, J. W., American Society of Agronomy, Madison, WI.

Xu, G., et al. (2017). Complex genetic architecture underlies maize tassel domestication. *New Phytologist*, 214:852–864.

Zhang, T. (1998). The estimation of maize (*Zea mays* L.) pollen viability and determination of its genetic effects. *M.S. thesis*. University of Nebraska, Lincoln, Nebraska.

Zsubori, Zs., Gyenes-Hegyi, Zs., Illés, O., Pók, I., Rácz, F., Szőke, Cs. (2002). Inheritance of plant and ear height in maize (*Zea mays* L.). *Acta Agraria Debreceniensis*, 8:34–38.