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INHERITANCE OF LEMMA COLOR, SEED COLOR AND PANICLE FORM AMONG FOUR CULTIVARS OF ERAGROSTIS TEF (ZUCC.) TROTTER

The University of Nebraska - Lincoln PH.D. 1981

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INHERITANCE OF LEMMA COLOR, SEED COLOR AND PANICLE FORM AMONG FOUR CULTIVARS OF ERAGROSTIS TEF (ZUCC.) TROTTER

by

Tareke Berhe

A DISSERTATION

Presented to the Faculty of
The Graduate College in the University of Nebraska
In Partial Fulfillment of Requirements
For the Degree of Doctor of Philosophy

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Under the Supervision of Dr. Lenis A. Nelson and
Dr. John W. Schmidt

Lincoln, Nebraska
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TITLE

Inheritance of Lemma Color, Seed Color and Panicle Form Among Four Cultivars of *Eragrostis tef* (Zucc.) Trotter

BY

Tareke Berhe

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INTRODUCTION

Teff (Eragrostis tef (Zucc.) Trotter) is one of the major cereal food grains of Ethiopia and an immediate and extensive improvement program is needed. It has excellent nutritive value, high consumer preference, and it is a high-value cash crop. This crop in Ethiopia occupies over two million hectares which is more than one-third of the total area under cereal crops in that country. Teff researchers including Berhe (1975), Ebba (1975), Assefa (1978) and Anonymous (1980) believe that teff will continue to be an important crop of Ethiopia for a long time to come. However, breeding work on the crop is just starting and genetic information is minimal.

Crossing techniques were developed at the end of 1974 by Berhe (1975) and the first successful crosses were made. Before that, teff breeding was carried out only through simple mass selection. Maximum yields of the varieties produced by mass selection are approximately two metric tons per hectare with optimum field management practices. The national average teff yield is still less than one ton per hectare. The major constraint to higher teff yields is believed to be the low yield potential of the present varieties coupled with production problems such as lodging, shattering and susceptibility to diseases, mainly teff rust (Uromyces eragrostidis Tracy) and head smudge (Helminthosporium myakei Nisikado). These problems clearly indicate that a strong teff breeding program is long overdue. There is an urgent need to raise the present yield if teff is to continue as an economical food grain.

In order to develop a sound breeding program for any crop, knowledge of the basic genetics of the crop is a prerequisite. For instance,

if it could be established that teff is an allotetraploid with diploid pairing and segregation, the procedures used to estimate genetic variance and heritability for diploids could be used.

The purpose of this research was to study the inheritance of three basic traits: lemma color, seed color and panicle form. These qualitative traits have economic value because according to Ebba (1975) and Costanza et al. (1979) they constitute the basis for the botanic and commercial classification of teff cultivars. The main objectives of this study were to determine: (1) the number of genes controlling each trait, (2) the gene action and interactions, (3) presence or absence of linkage, (4) presence or absence of maternal effects and (5) whether teff is an auto- or allo-tetraploid.

As emphasized by Assefa (1978), there is a need for standardizing teff research and nomenclature. With this in mind, cultivar names and color codes established by Ebba (1975) have been adopted in this study as much as possible unless otherwise indicated. However, two changes were made. First, the most common epithet "teff" as used by Mengesha (1964) and Assefa (1978) was adopted instead of Ebba's "te'f." Second, Ebba's descriptions of panicle forms as very loose, fairly loose and compact were used to describe degree of looseness only. The botanic terms effusum, contractum, and compactum were used whenever it was necessary to consider both degree of looseness and pattern of branching. Effusum will represent loose-multilateral, contractum loose-unilateral, and compactum compact-multilateral panicle forms.

In the body of the paper, Ethiopian authors are cited by their second name for the sake of conformity. However, since people are

identified better by the first name in Ethiopia, the first names of Ethiopian authors are fully spelled out in the "Literature Cited" section.

Gene symbols that are commonly used in other cereals and millets have been adopted in order to maintain a language of higher internationality. The rules recommended by the International Committee on Genetic Symbols and Nomenclature (1957) were also closely observed.

LITERATURE REVIEW

Teff Botany, Cytogenetics and Breeding

Teff is an annual grass crop belonging to the genus Eragrostis. The best reference on teff botany is that of Ebba (1975). Others include those by Mengesha (1964), Mengesha et al. (1965), Rouk and Mengesha (1965) and Assefa (1978). The plants vary in average height from the short cultivars: "Bunniye," "Gea-Lamie" and "Shawa-Gemerra" (30-35 cms) to the tall cultivars: "Gomadie," "Hattalla" and "Murri" (90-95 cms). It takes 35-55 days for teff plants to head and 75-120 days to mature.

a. Inflorescence

The inflorescence is a panicle, 15-45 cms in length, with primary, secondary, tertiary and, in some cases, quaternary panicle branches. There are two main panicle forms, loose and compact, with four basic inflorescence colors: yellowish-white, gray, red and purple. All are easily recognizable. In his detailed studies, Ebba (1975) classified two more intermediate panicle forms, fairly loose and semi-compact. The four panicle types were described as follows: (1) very loose - primary panicle branches symmetrically ramified, central rachis fully exposed; (2) fairly loose: a. primary panicle branches almost symmetrically ramified, central rachis fully exposed; b. primary panicle branches asymmetrically ramified, central rachis not fully exposed; and c. panicle branches unilaterally ramified, central rachis not fully exposed; (3) semi-compact - panicle branches asymmetrically ramified with central rachis not fully exposed; and (4) very compact - central rachis completely covered with panicle branches that grow adhering to the main

rachis.

Assefa (1978) examined 16 cultivars representing the above categories and described the degree of looseness or compactness of a panicle in terms of the angle between the central axis and the primary branches extending from it. According to this description a very compact panicle approached a zero degree angle and a very loose one an angle of 90 degrees. He also noted that these morphological traits remained true to type under various environmental conditions. Ebba (1975) and Assefa (1978) described teff panicles as having pedicellated spikelets. Each spikelet contains 4 to 12 florets. The number of spikelets per panicle ranges from 60 to 600.

b. Pollination

Anthesis begins about 6 a.m. and lasts for a maximum of two hours. This was first noted by Berhe (1975, 1976). On a panicle basis, pollination progresses basipetally, i.e., spikelets at the apex mature first. On the other hand, flowering progresses acropetally within each spikelet. Normally, flowering takes place on a one floret/spikelet/day basis. Hence, it takes almost one to two weeks for a spikelet and three to four weeks for a panicle to complete flowering. At maturity, each fertile floret produces a single naked seed (caryopsis) whose average size as reported by Ebba (1975) is 0.9 to 1.7 mm in length and 0.7 to 1.0 mm in diameter. Seeds are ovoid to ellipsoidal in shape and brownish to yellowish-white in color.

c. Cytogenetics

Teff is a sexual crop that is self-pollinated. The first cytological evidence of sexuality in teff came from Mengesha's pioneer study

at Purdue on the crop's embryo-sac development which was published by Mengesha and Guard (1966). They reported that the embryo-sac is a normal monosporic type with evidence of double fertilization. Self-pollination was supported by "progeny tests from single and mutually bagged heads." Berhe and Miller (1978) in later studies confirmed Mengesha and Guard's findings and also reported that microsporogenesis culminated in tri-nucleate pollen grains. Assefa and Drolsom (1976) and Jones et al. (1978) reported that teff has a chromosome number of 2n = 40. Since the basic chromosome number of the genus Eragrostis is 10 (Darlington and Janaki Ammal, 1945), teff is considered to be a tetraploid. It is not known whether it is an auto- or allo-tetraploid. Some indications point towards allo-tetraploidy. Cytological observations made by Jones et al. (1978) showed bivalent pairing. Jones (1980) is convinced that "teff is either an allo-tetraploid or an effectively diploidized auto-tetraploid." He predicted that teff would show disomic inheritance.

d. Breeding

Prior to 1974, teff breeding by conventional methods was considered impossible because of the extremely tiny florets which failed to set seed upon emasculation and subsequent pollination. As a result, teff breeding was carried out only by mass selection from germplasm collections. The very popular varieties DZ-01-196, DZ-01-354 and DZ-01-99 were developed by this method. In late 1974, the critical early-morning flowering period of teff was discovered by Berhe (1975, 1976). Cross breeding and selection were continued between 1975 and 1980. According to the latest report (Anonymous, 1980), some promising selections have reached the National Yield Trial stage.

In the first successful crosses, Berhe (1975, 1976) observed that seed and lemma colors plus panicle form served as very useful markers. Dominance was displayed by loose panicle, colored lemma and colored seeds over compact panicle, yellowish-white lemma and white seed, respectively. No reports were made on the number of genes involved with these traits or their specific actions.

The development of crossing techniques has produced better opportunities for teff improvement. Considerable breeding progress can be expected because of the tremendous variability which has been reported in teff by Rouk and Mengesha (1965) and Mengesha et al. (1965), and later confirmed by Ebba (1975) when 35 distinct cultivars were classified on the basis of "color of the grains and inflorescences, ramification of the panicles and the size of the plants."

Inheritance of Lemma Color

Teff has purple, red, gray or yellowish-white lemmas. These colors are important in the classification of the crop into different cultivars. Even many of the vernacular names carry prefixes[+] such as Kay, Hamrawe, Hatalla and Adi which stand for red, purple, gray and white, respectively. Ebba (1975) used these lemma colors as one of the major taxonomic classification indices while grouping the teff germplasm into 35 distinct cultivars. At about the same time, Berhe (1975, 1976) used lemma colors as possible gene markers while trying to develop cross-breeding techniques for the crop. He reported that, based on the F_1 (first filial generation), colored lemmas were dominant over non-

[+] The prefixes are in the Ethiopian languages as indicated. Kay (Amharic), Hamrawe (Amharic), Hatalla (Tigrignia), Adi (Oromignia).

colored ones and that a red by gray cross came out to be purple. No other information is available on the inheritance of lemma colors in teff. However, inheritance of lemma colors has been thoroughly studied in other cereals and millets and will be briefly reviewed for providing comparative information. In barley (Hordeum vulgare L.), oats (Avena sativa L.), rice (Oryza sativa L.) and several of the millets, the lemmas remain affixed to the seed and therefore, lemma colors have been reported as seed colors in the literature. They will be reviewed as lemma colors in this study.

Oats is one of the crops in which inheritance of lemma color has been thoroughly studied. Jensen (1961) made a detailed review on the subject. He pointed out that, among others, red, gray and white lemma colors are present in oats. In many studies, gray by white crosses gave 3:1 F_2 (second filial generation) and F_3 (third filial generation) ratios with gray being dominant over white. Red by white crosses resulted in a lighter red F_1 and segregated into red, gray, yellow and white in F_2. Two-factor inheritance patterns were observed by F_2 ratios of 12 red:3 gray:1 yellow and three-factor ratios by 48 red:12 gray:3 yellow:1 white.

In rice, lemma colors are usually white but sometimes purple and red pigments are present. While conducting linkage studies, Chao (1928) obtained F_2 ratios of 3:1, 9:7, 15:1, 27:37 and 162:94 from colored versus non-colored crosses. He concluded that at least four complementary genetic factors were responsible for the production of colors on the apex of the lemma and palea. Later, Jones (1930) explained the inheritance of purple and red lemmas on the basis of three dominant