

INFORMATION TO USERS

This manuscript has been reproduced from the microfilm master. UMI films the text directly from the original or copy submitted. Thus, some thesis and dissertation copies are in typewriter face, while others may be from any type of computer printer.

The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleedthrough, substandard margins, and improper alignment can adversely affect reproduction.

In the unlikely event that the author did not send UMI a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.

Oversize materials (e.g., maps, drawings, charts) are reproduced by sectioning the original, beginning at the upper left-hand corner and continuing from left to right in equal sections with small overlaps.

ProQuest Information and Learning
300 North Zeeb Road, Ann Arbor, MI 48106-1346 USA
800-521-0600

UMI[®]

PREVIEW

**MATERNAL AND CYTOPLASMIC EFFECTS ON COMPONENTS OF
SORGHUM GRAIN YIELD**

by

Jose Antonio Hernandez-Alatorre

A DISSERTATION

Presented to the Faculty of

The Graduate College at the University of Nebraska

In Partial Fulfillment of Requirements

For the Degree of Doctor of Philosophy

Major: Agronomy

Under the Supervision of Professor Jerry D. Eastin

Lincoln, Nebraska

July, 2002

UMI Number: 3064577

UMI[®]

UMI Microform 3064577

Copyright 2002 by ProQuest Information and Learning Company.
All rights reserved. This microform edition is protected against
unauthorized copying under Title 17, United States Code.

ProQuest Information and Learning Company
300 North Zeeb Road
P.O. Box 1346
Ann Arbor, MI 48106-1346

DISSERTATION TITLE

Maternal and cytoplasmic effects on components of sorghum

grain yield


BY

Jose Antonio Hernandez-Alatorre

SUPERVISORY COMMITTEE:

APPROVED

DATE


Signature


Dr. Jerry D. Eastin
Typed Name

2 Aug 2002


Signature

Dr. Dale L. Van Vleck
Typed Name

30 July 02


Signature

Dr. Lenis A. Nelson
Typed Name

30 July 02


Signature

Dr. Stephen D. Kachman
Typed Name

7-30-02

Signature

Typed Name

Signature

Typed Name



MATERNAL AND CYTOPLASMIC EFFECTS ON COMPONENTS OF SORGHUM GRAIN YIELD

Jose Antonio Hernandez-Alatorre, Ph.D.

University of Nebraska, 2002

Adviser: Jerry D. Eastin

Knowledge of maternal and paternal contributions of segregating families to yield components should be useful for generating hybrids with higher yield potential of sorghum.

Reciprocal crosses between population steriles and fertile pollinators and two A/B lines differing in seed number and seed weight were used to examine whether maternal effects on seed number and seed weight contribute substantially to grain yield. The sources of experimental material were one large-seeded parent (Wheatland inbred line), one small-seeded parent (46038 inbred line), and a range of male and female parents from the Nebraska Seed Size Population (NSSC₅). Measurements from generations P1 (parent 1 = population), P2 (parent 2 = inbred line, either 46038 or Wheatland), F1, F2, BC1 (backcross 1) and BC2 (backcross 2) were obtained in two experiments, one under field conditions and another under greenhouse conditions. Traits measured were grain yield, yield components and respiration rates through the development of the plant. The genetic analyses included analysis of fixed and random effects with the Multiple Trait Derivative Free Restricted Maximum

Likelihood program (MTDFREML). The analysis of random effects used pedigree and inbreeding information. The model included random direct and maternal genetic effects and cytoplasmic effects.

Results suggest that maternal effects were important for yield, seed number and seed weight. Cytoplasmic effects were more important for yield and seed number than for seed weight. Respiration rates seem to be controlled primarily by maternal inheritance. Direct genetic effects were more important for yield and seed number than for seed weight. When the model includes maternal and/or cytoplasmic effects, estimates of direct genetic variance were usually reduced.

PREVIEW

In Memory of my Mother and my Father:

Maria Antonia Alatorre de Hernandez

and

Jose Isabel Hernandez Torres

This dissertation is dedicated to my wife Laura Imelda, my daughters Maria Imelda and Monica and my son Jose Antonio. This is dedicated also for my brothers and sisters: Gerardo, Jorge, Luis, Mario, Carmela and Ana Isabel.

ACKNOWLEDGEMENTS

I would like to thank to the National Institute of Forestry, Agriculture and Livestock Research (INIFAP) and the National Council of Science and Technology (CONACYT) from Mexico for providing financial support during my Ph. D. program. Thanks also to the Nebraska Grain Sorghum Utilization, Development and Marketing Board for research operational support for doing my research in the field and in the greenhouse.

I am especially grateful to Dr. Jerry D. Eastin for his excellent guidance throughout my Ph. D program. I acknowledge to him not only for his support in the academic part, but also for his support concerning very different activities during my program.

I would like to thank to Dr. Dale L. Van Vleck for his exceptional assistance in the analyses of data, and Dr. Lenis A. Nelson for his positive criticism in the review of the present document. Thanks to both of them for being part of my reading committee. Thanks to Dr. Stephen D. Kachman for being part of my supervisor committee and for his exceptional interest to improve the analysis and interpretation of data.

I would like to extend sincere thanks to all my professors at UNL. Special thanks to Dr. Francisco Zavala-Garcia who participated in my research in the field and reviewing manuscripts.

I express my sincere thanks and love to my wife Laura, my daughters Maria Imelda and Monica and my son Jose Antonio, I am sure they like me had a great experience in this beautiful country. I am proud of them.

Finally, I acknowledge to my friends Andres Ramiro Cordova and Carlos Espinosa Zapata who from long distance gave me their moral support and their friendship.

PREVIEW

TABLE OF CONTENTS

v

INTRODUCTION.....	1
CHAPTER 1	
MATERNAL AND CYTOPLASMIC EFFECTS ON COMPONENTS OF SORGHUM GRAIN YIELD.....	4
ABSTRACT.....	5
LITERATURE REVIEW	7
Maternal and paternal genetic contributions on yield and other traits	
MATERIALS AND METHODS	12
Genetic material	12
Experimental design	14
Agronomic management	15
Traits measured	15
Statistical analyses	16
Genetic analyses	17
Estimates of proportions of variances	23
Genetic correlations	23
RESULTS	28
Grain yield	28
Seed number	31
Seed weight	32

	vi
Panicle length, plant height and maturity	33
Genetic correlations	33
DISCUSSION	35
CONCLUSIONS	39
REFERENCES	40
 CHAPTER II.....	 70
MATERNAL EFFECTS ON SORGHUM IN RELATION TO PLANT BIOMASS PRODUCTION AND GROWTH RESPIRATION.....	70
INTRODUCTION.....	71
LITERATURE REVIEW	73
MATERIALS AND METHODS	80
Genetic material	80
Experimental design	82
Greenhouse environmental conditions	82
Traits measured	83
Plant respiration monitoring.....	84
Statistical analyses	86
Genetic analyses	87
Estimates of proportions of variances	89
Genetic correlations	90
RESULTS	91

	vii
Seedling emergence.....	91
Seedling vigor.....	92
Plant height.....	92
Dry weight.....	93
Respiration rates (Rs).....	93
Yield and yield components.....	95
Genetic correlation.....	95
DISCUSSION	97
REFERENCES	99
APPENDIX.....	117
Table A1.1. Original data of the crosses NSSC₅ X 46038 and NSSC₅ X Wheatland their reciprocals and fifteen progenies analyzed with MTDFREML program. Havelock, 2001	118
Table A1.2. Additive relationship matrix (A) used for estimate direct, maternal and cytoplasmic effects of NSSC₅ X 46038 and NSSC₅ X Wheatland sorghum crosses and their reciprocals. Havelock, 2001.....	119
Table A 1. 3. Coefficients of expected genetic parameters for sorghum grain yield and yield components in a cross between a random mating population and an inbred line. Taking the F2 as a reference.....	120
Table A 1.4. Least squares means and standard errors for (46038 X	

NSSC ₅) and (Wheatland X NSSC ₅) crosses and their reciprocals for grain yield (kg ha ⁻¹). Havelock, 2001.....	121
Table A 1.5. Least squares means and standard errors for (46038 X NSSC ₅) and (Wheatland X NSSC ₅) crosses and their reciprocals for seed number (seeds per plot-6.56 m ²). Havelock. 2001.....	122
Table A 1.6. Least squares means and standard errors for (46038 X NSSC ₅) and (Wheatland X NSSC ₅) crosses and their reciprocals for seed weight (g/500 seeds). Havelock, 2001.....	123
A 1. 7. Correct relationships within F1, F2, BC1 and BC2 families used for estimate direct, maternal and cytoplasmic effects in the analyses of (46038 X NSSC ₅) and (Wheatland X NSSC ₅) sorghum crosses and their reciprocals. Havelock. 2001.....	124
Table A 2.1. Original data of the crosses NSSC ₅ X 46038 and NSSC ₅ x Wheatland their reciprocals and three progenies evaluated under greenhouse conditions. 2001 (CD attachment).....	125
Table A 2.2. Formula used by the licor-6200 analyzer in calculating photosynthesis and respiration.....	126
Table A 2.3.1. Standard deviations used for standardization of respiration rate (Rs) observatios for sorghum NSSC5 X 46038 and NSSC5 X Wheatland crosses and their reciprocals. Greenhouse experiment, 2001.....	127

Table A 2.3.2. (Continued) Standard deviations used for standardization of observations for NSSC5 x 46038 and NSSC5 x Wheatland crosses and their reciprocals. Greenhouse experiment, 2001	127
Table A 2.4. Standard deviations used for standardization of observations for sorghum crosses NSSC ₅ x 46038 and NSSC ₅ x Wheatland and their reciprocals. Greenhouse experiment. 2001	128
Table A 2.5. Least squares means and standard errors for crosses and generations for seedling emergence. Greenhouse experiment. 2001	129
Table A 2.6. Least squares means and standard errors for crosses and generations for seedling vigor. Greenhouse experiment. 2001	130
Table A 2.7. Least squares means and standard errors for crosses and generations for dry weight. Greenhouse experiment. 2001	131
Table A 2.8. Analysis of variance for yield per plant, seed number and seed weight. Greenhouse experiment. 2001	132
Appendix CD Rom raw data pages 1 through 64.....	133

INTRODUCTION

Commercial sorghum (*Sorghum bicolor* L.) hybrid development is done almost solely via standard pedigree line development methodology with very little input from commercial population development. Furthermore there are few public institutions where random mating populations play a significant role in improved line and /or hybrid development. Given the comparatively large number of recombinations possible within random mating populations compared to line breeding programs alone, careful use of selectively synthesized populations would seem to offer utility in improving grain yields via manipulation of the main yield components seed weight and seed number.

The primary abiotic adaptation of interest for most sorghum production environments are high temperature and water stress tolerances. Therefore, a tan plant color (food grain type) population NP39R was developed (using genetic male sterility *ms₃*) cooperatively in Western Kansas (hot, dry environments) with Kansas State University scientists. Selection pressure was set up to screen for a high, comparatively stable seed number that resulted in high seed number population genotypes with relatively small seeds, good water/high temperature stress tolerances and high yield potentials.

Simultaneous to development of NP39R, testing of hybrids of other stress tolerant lines in hybrid combinations revealed that the highest yielding hybrids consistently had larger seeds under both good and stress conditions which is contrary to the current general belief that when seed weight goes up yield goes

down and vice versa. Therefore, it seemed prudent to put genes for larger seed weight into the stress resistant NP39R population, which gave rise to the NSSC₅ (Nebraska Seed Size Population), cycle 5 which was used in the current study.

Further, it seemed that optimum utilization of NSSC₅ type of populations might be more likely to be realized through identifying potentially favorable contributions of maternal and paternal sources from segregating genotypes selected within the population which is quite diverse in terms of seed weight and seed number yield components. Such identification of maternal and paternal contributions from population genotypes to both seed weight and seed number components to hybrid yields is the overall objective of this research. This would permit the identification of which lines (or segregating population genotypes) should be used as female parents and which lines (or segregating population genotypes) would serve best as pollinators in hybrid breeding programs.

The specific contributions of parents to progeny have been studied since the beginning of plant breeding. Maternal effects are mainly of two types: genetic (effect of the mother in addition to the genetic effects of the sample one-half of her genes transmitted to her offspring (Van Vleck, 1993), and cytoplasmic (cytoplasmic genetic maternal effects are derived from the fact that organelles such as plastids and mitochondria can be directly transferred from the maternal plant to the offspring during ovule formation and development, and this transmission is independent of nuclear genes (Roach and Wulff, 1987). Paternal effects can be xenia effects of pollen grains on the endosperm of the mother plant plus normal genetic effects on virtually all yield dependent metabolic and

developmental processes. Maternal effects have been traditionally estimated by comparing the F1 hybrids from reciprocal crosses, while cytoplasmic effects have been estimated by comparing the F2 populations derived from reciprocal F1's or from the backcrosses using the reciprocals F1's as seed parents (Mosjidis and Yermanos, 1984).

Research on maternal and paternal contributions usually has been done by using inbred lines as parents with very little study of open pollinated varieties or segregating genotypes from random mating populations. When inbred lines are used as parents, the main objective is the study of their means, which can be done with analysis of diallel crosses (Cockerham and Weir, 1977) or with generation means analysis (Barnes, 1968; Mosjidis et al. 1989). When selections from open pollinated varieties or randomly mating populations are utilized as parents, the objective is to estimate not only means but also variances and covariances. These estimates can be obtained by using composite effects models (Lynch and Walsh, 1998) or mixed model equations (Henderson, 1975).

Mixed model equations have been used for estimating maternal effects in animal breeding research (e.g., Van Vleck, 1993) and could be adapted for estimating genetic effects in plants when variation is expected from segregating populations.

CHAPTER 1

MATERNAL AND CYTOPLASMIC EFFECTS ON COMPONENTS OF SORGHUM GRAIN YIELD

ABSTRACT

The identification of lines and families of grain sorghum (*Sorghum bicolor* L.) for increasing seed size and seed number components of yield, hopefully simultaneously, from randomly mated populations featuring wide ranges of seed weights and seed numbers could serve as an effective breeding method.

Progress in developing more favorable gene combinations for increasing yields to complement the usual inbred line crossing method being used commercially might be improved through identification of maternal and paternal source effects of various randomly mated population derivatives.

Information regarding the maternal and paternal contributions of segregating families may be useful for generating hybrids with higher yield potential. Reciprocal crosses between population steriles and fertile pollinators and two A/B lines differing in seed number and seed weight were used to examine whether maternal effects on seed number and seed weight may contribute to grain yield. The sources of experimental material were one large-seeded parent (Wheatland inbred line), one small-seeded parent (46038 inbred line) (including the A and B versions of each inbred line), and a range of male and female parents from the Nebraska seed size population (NSSC₅).

Measurements from generations P1 (parent 1 = population), P2 (parent 2 = inbred line), F1, F2, BC1 (backcross 1) and BC2 (backcross 2) direct and reciprocals were obtained in two experiments, one under field conditions and another carried out under greenhouse conditions. Traits measured were 500-

grain weight, grain number per plot and grain yield. The genetic analyses included analysis of fixed and random effects with the Multiple Trait Derivative Free Restricted Maximum Likelihood program (MTDFREML). The analysis of random effects used pedigree and inbreeding information. The model included random direct and maternal genetic effects and cytoplasmic effects.

The results suggest that maternal effects were important for yield, seed number and seed weight. Reciprocal effects were different for most of the F1 progenies. Significant variation due to maternal effects was found. Cytoplasmic effects were more important for yield and seed number than for seed weight. Persistent differences between reciprocal crosses were observed for most of the filial generations. Most of the variance due to cytoplasmic effects originated from cytoplasmic sources from the NSSC₅ population and the 46038 inbred line. Respiration rates seem to be maternally inherited.

Direct (additive) genetic effects were more important for yield and seed number traits than for seed weight. Direct genetic effects usually were associated with low estimates of genetic variance and heritability when included in the model together with maternal and/or cytoplasmic effects.

LITERATURE REVIEW

Maternal effects can be detected and analyzed easily and unambiguously for inbred lines. Inbred lines are not, however, needed for this purpose in all circumstances. With hermaphroditic species, each individual can be used both as a maternal and paternal parent so that maternal effects can be detected by making crosses reciprocally between pairs of individuals irrespective of whether they are homozygous or heterozygous (Mather and Jinks, 1971).

Maternal effects have been studied in different crops for various traits. Singh and Hadley (1972) reported results from experiments designed to determine the effects of cytoplasm and genotype of the maternal parent on protein content in soybean (*Glycine max* L.) seeds. Maternal effects were estimated by comparing means of F1 seeds with those of selfed seeds on the same female parental plants. Cytoplasmic effects were detected by comparing means of F2 seed borne on F1 plants from reciprocal crosses. Their main results indicated that the mean of F1 seeds did not differ from that of selfed seeds produced in the same plant which suggests strong maternal effects.

In sorghum, (*Sorghum bicolor* L.) Eastin et al. (1998), from physiologically based screening, found that the "Wheatland" x 17473 hybrid grain sorghum mean of 7,367 kg ha⁻¹ exceeded the Tx 3042 hybrid mean of 6,476 kg ha⁻¹ by 14%, even though the Tx 3042 hybrids have 23,200 seeds m⁻² compared with the 19,300 seed m⁻² for the Wheatland hybrids (11% superiority for Tx 3042 hybrids). The yield of Wheatland hybrid was superior because the seeds were

26% larger (3.53 vs. 2.81 g 100 seeds⁻¹). With pollinators being common and females being different, seed size was clearly a female effect in their experiment.

Diallel-crossing methodology has been used extensively in the past for estimating maternal effects. More recently generation means analysis has been used for estimating maternal effects

Corey et al. (1976) used a diallel model to study maternal and cytoplasmic effects on three seedling characters of F1 hybrids of *Arabidopsis thaliana* (L.) Heyuh'. Evidently, they used inbred lines as parents. Effects in their model included mean, nuclear genetic effects of the parents, nuclear genetic interaction effect of the parents, effect of maternal cytoplasm, interaction effects of the cytoplasm and the nuclear genetic contributions of the parents. The model was similar to that presented by Yates (1947) and Cockerham (1963).

Barnes (1968) reported results from an analysis of the genetic system controlling number of progeny of *Drosophila melanogaster*. The parental, F1, F2 and backcross generations, including all reciprocals, of two inbred lines were raised in each of three fully randomized blocks. The mean, additive and dominance effects were estimated by weighted least squares using as weights the reciprocals of the variances of the generation means. Maternal effects were estimated by an additional parameter [f]. In the comparison between the observed and expected generation means, the χ^2 test with degrees of freedom equal the number of generation means minus the number of parameters estimated showed that the model adequately summarizes the data. The

important components of the model were dominance in the direction of higher progeny number, and maternal effects associated with the F1.

In a similar way, Tyson (1973) made crosses between four flax (*Linum usitatissimum*) genotypes to generate F1, F2 and backcross generations. Unequal sub-class numbers were handled by an appropriate least-squares procedure, and comparisons were made among the estimated means of progenies. No differences between reciprocal F1 hybrids were detected.

In animal breeding maternal effects have been estimated by using a variety of programs and the MTDFREML set of programs (Boldman et al. 1993). The MTDFREML program has been used for the analysis of genotype x environment interactions in experiments with plants (Rodriguez-Herrera, 1992 and Coutiño-Estrada, 1998) but could also be used in analyses of genetic effects.

Regarding paternal effects Leng (1949), in his classical work on the direct effect of the pollen parent on kernel size in dent corn, found that when used as pollen parents certain inbred lines were found to differ significantly in their effects on the weight of F1 kernel. Pollen effects from the R₄ inbred line reduced weight as much as 20%, as compared with effects of pollen from a number of other inbred lines. This depressing effect on kernel weight was observed in all crosses in which R₄ was the pollen parent.

Burton et al. (1980) conducted research to study the pollen parent effect on several chemical components in pearl millet (*Pennisetum americanum* L.) grain. They found that the female effect was greater than the male effect. However, open-pollinated seed was significantly superior to self-pollinated seed