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Cytoplasmic Inheritance of High Tillering and Earing Characters of a Korean Local Maize Line(MET)

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多穗・多蘖性 옥수수(MET)의 細胞質的 遺傳

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ABSTRACT

A Korean local maize line, MET, which has multi-ears and tillers has been proved as a potential source for silage production. However, no fundamental genetic nature for the line has been investigated. Therefore, this study was done to find genetic information on the multi-earing and -tillering habits of MET line. MET line and a hybrid, (Mo 17 x B68), with monoculm and single ear per plant were used for production of F_1 (F_{1-12} and F_{1-21}), F_{2-12}, F_{2-21}, BC_{1-12} and BC_{1-21} generations. From the comparison of reciprocal crosses, it was found that the tillering and earing habits of the MET line are controlled by cytoplasmic factors. The tiller and ear numbers, and barren ears were all characters associated with the MET cytoplasm. The cytoplasmic effect of MET on tiller and ear numbers was not evident in F_1 generation, probably because of suppressing effect of heterosis on appearance of tillers or ears. Genetic parameters for the gene action for both tiller and ear number also indicated a lack of mono- or digenic-chromosomal gene effects. The heritability (broad) was very low for both characters. Therefore, it is strongly concluded that the tillering and earing characters of MET line are due to cytoplasmic reasons.

INTRODUCTION

Most hybrid maizes are having no tillers and bearing one ear per plant. A few exception to this is found in some sweet corn hybrids. But the tillers in some sweet corn hybrids are not bearing harvestable ears. Also those tillers born by most maize are not wanted either by farmers or by maize breeders.

Since 1970's, some maize breeders[4,5,6,8,9,10] in the U.S. have been attempted to develop hybrids with prolificacy. The main purpose for this is to attain more harvestable ears when plant populations per unit area are high, because most hybrids are barren under the certain high population density. Tracy and Everett[11] reported studies on penetrance and expressivity of grassy tiller in maize as a possible source for silage material. Ellsworth and Peloquin[4] postulated some cytoplasmic effects on ear number.

Choe et al.[1,2,3] reported that one maize line found among their local maize lines collected in Korea had six tillers and 12 ears per plant under

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favorable condition. They also reported that the high tillering and earing habits are rather genetic and they named the line as multiple eared and tillered (MET) line. Choe et al.[2,3] compared dry matter production of MET with ordinary monoculm maize hybrid, and they found that the total dry matter production of the MET was not lower than that of check hybrid, MO17 x B68, under various environmental conditions. They suggested the possible use of MET for silage purpose. Knowing genetic nature of the high tillering and earing habits of the MET will be necessary to further evaluation and utilization of the line. Therefore, the objectives of the study were to obtain more crucial information on the genetic nature of the high tillering and earing habits of the MET line and to discuss the possible use of the characters for future maize breeding works.

MATERIALS AND METHODS

Only two varieties, MET and (MO17 x B68), were used in cross. MET was designated as parent 1 (P1) and (MO17 x B68) as parent 2 (P2). F_1 seeds were produced by cross and reciprocal cross between two varieties and designated as F_{1-12} and F_{1-21}, respectively. F_2's were produced by selfing F_1 plants and designated as F_{2-12} F_{2-21}, respectively. Also back crosses were made by backcrossing F_{1-12} to MET and F_{1-21} to (MO17 x B68) and designated as BC_{1-12} and BC_{2-12}, respectively.

Seeds from 8 different crosses and generations were grown in 1982 at Agricultural College farm, Chungnam National University. Each entry was entered into randomized block design with 10 replications. Each plot was consisted of 2 rows. The plot size was 5 meters long and 1.2 meters wide. 18 plants per row were spaced 30cm apart. Two kernels were planted and later thinned to one plant per hill. The characters studied were number of tiller per plant, number of ears per main stem, number of tillers per plant at each developmental stage, number of barren ears per plant and grain yield per plant. The ear number weight index and tiller weight yield index were also studied.

The genetic analysis for each plant character was followed due to Mather and Jinks's[7] generation mean analysis and Duncan's multiple range test were also used for mean comparison. Estimates of broad sense of heritabilities of tiller and ear number per plant were calculated based on the genetic variance to the total F_2 variance.

RESULTS AND DISCUSSION

Mean Comparison

The mean values of plant characters of each generation at harvesting stage were shown in Table 1 and their statistical significances were also shown. The average number of tillers per plant was 3.38 for MET (P1) and none for (MO17 x B68) (P2). However, there was no apparent difference in average tiller number between F_{1-12} and F_{1-21} crosses, showing no reciprocal effects. No reciprocal effects were also observed in F_2 generations of either F_{2-12} or F_{2-21}. Nevertheless, significant differences in the tiller numbers were found when recurrent parents were different in backcrosses. For instance, the mean number of tiller per plant was greatly increased when recurrent parent used was MET. The increase of tiller numbers when MET was used as recurrent parent in backcross indicates strongly that there may be maternal effects. The reason why those maternal or dosage effects of MET on the tiller numbers couldn't be observed in both F_{1-12} or reciprocal F_{1-21} generations may be explained by heterosis for apical dominance manifested in F_1 hybrids. In other words, the heterosis shown for plant height in F_1 generation was so high that appearance of tillers in F_1 plants might be suppressed. However, the heterosis in BC_{1-12} generation was not so high that the tillers could be appeared. It should be indicated that no mendelian segregation for tiller numbers was observed during F2 or backcross generations. This indicates also that the genes involved in tillering characters of MET may be not chromosomal genes but cytoplasmic ones.

Number of ears per main stem had the similar

Table 1. Mean number of tillers and ears per plant and kernel yield per plant.

Generations	Tillers	Ears	Yield, gr.
P1 (MET)	3.38a*	2.63a	136.9b
P2 (Mo17 x B68)	0.0	1.0e	149.7a
F_{1-12} [MET x (Mo17 x B68)]	2.01b	1.28b	146.7a
F_{1-21} [(Mo17 x B68) x MET]	1.99b	1.28d	143.0ab
F_{2-21} [MET x (Mo17 x B68)]	1.09c	1.50b	102.5c
F_{2-21} [(Mo17 x B68) x MET]	1.27c	1.35cd	122.0d
BC_{1-12} (MET x F_{1-12})	1.92b	1.48b	142.6ab
BC_{1-21} [(Mo17xB68) x F_{1-12}]	0.32d	1.03e	112.8cd

*Mean values with different superscripts are significantly different at 5% level.

patterns of inheritance as the number of tillers. As shown in Table 1, the mean ear number per plant was 2.63 for MET and 1.0 for (MO17 x B68). As the tiller number, there wasn't significant reciprocal cross difference in F_1 generation. Again it may be due to the high heterosis shown in F_1 and in reciprocal F_1 crosses. However, the mean number of ear in F_2 generation varied with crosses. F_2 of [MET (female) x (MO17 x B68) (male)] showed higher number of ears per main stem than the F_2 of *[(MO17 x B68) (female) x MET (male)]*. Such a reciprocal difference was more evident in backcross generations. When MET was used as recurrent parent, the ear number per main stem was higher than when the recurrent parent in backcross generation was (MO17 x B68). These facts indicate also that the ear number per plant of MET line is inherited cytoplasmically. In this respect, our study was closely agreed upon the report by Ellisworth and Peloquin[4].

The typical tillering habit among generations were shown in Fig. 1. Appearance of tillers in F_1 or MET line was earlier than that in BC_1 or BC_2 generations. However, the total percentage of tillering plants per generation was higher in BC_{1-12}, BC_{1-21} of F_2 generations compared with that in parent (MET) or F_1 generation. Fig. 1 shows that tillering is completed about 37 days after planting in most generations.

The distribution of tillers in each generation is shown in Fig. 2. The tillers of MET (P1) line was distributed from 2 to 5 with a mean of 3. The F_2 shows rather scattered distributions of tillers from

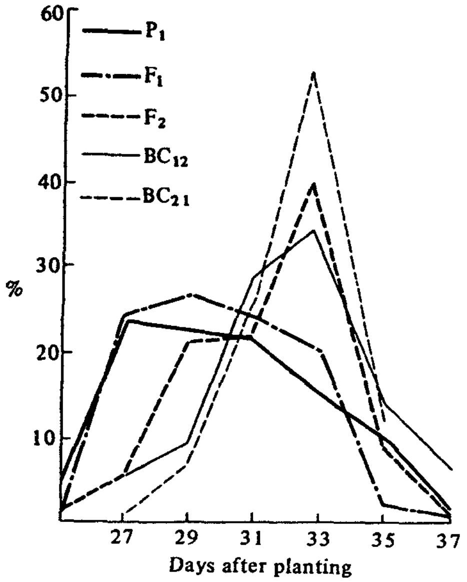

Fig. 1. Distribution of tiller emergence after planting.

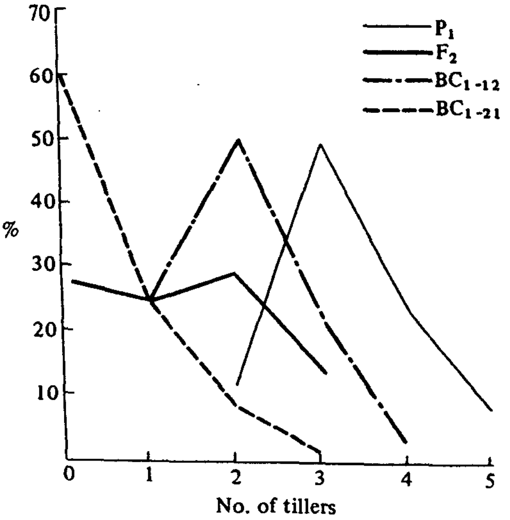

Fig. 2. Distribution of number of tillers of each generation.

Table 2. Weighted estimates of genetic parameters for tiller number.

Components Components	3-parameter model	6-parameter model
m	0.47±0.11**	0.13±28.73
d	1.70±0.08**	2.87±28.73
h	1.45±0.17**	2.27±86.18
i		0.57±0.43
j		-2.65±57.47
k		-0.16±57.46
$X^2(2)$	8.21(0.01<P<0.025)	

** Significant at 1% level.

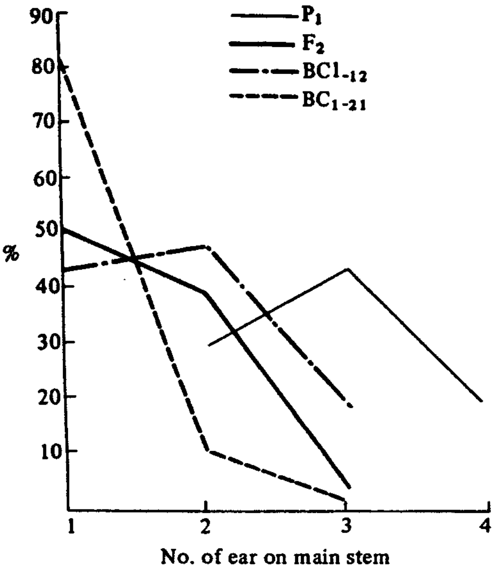

Fig. 3. Distribution of ear number of BC_1, BC_2, F_2 and P_1.

0 to 3. The tillers of BC_{1-12} between MET (female) and [MET x (MO17 x B68)] (male) were normally distributed from 1 to 4 with a mean of 2. The MET line and BC_{1-12} shows similar shape of distribution. However, the tiller distribution of BC_{1-21} between (MO17 x B68)(female) and [MET x (MO17 x B68)] (male) was skewed to left. As shown in Table 1, the mean number of tillers per plant in each generation was reduced as the generations proceeded. The reduction of tiller number per plant due to generations may be due to the dilution of MET genotypes. Our unreported data showed that tillering habits of MET line wasn't changed greatly when the line was selfed four consecutive generations.

The same patterns of distribution were found in the ear numbers per main stem (Fig. 3). The ear number in MET line and BC_{1-12} was rather normally distributed from 2 to 4, while the ear number in BC_{1-21} between (MO17 x B68) (female) and [MET x (MO17 x B68)] (male) was again skewed to left. The same explanation applied for the tiller number may hold for the ear number.

Estimate of Genetic Parameters

The genetic parameters were estimated by using Mather's generation mean analysis. Weighted estimates of additive (d) gene effects and dominance gene effect (h) for the tiller number per plant were highly significant. However, the X^2 value computed for joint scaling to test the fit of the additive-dominance model, indicated that estimates were biased to an unknown extent by effects not attributable to the additive-dominance action of genes (Table 3). In the digenic epistatic model with six parameters no significant parameters were obtained. The F_2 and BC_{11} generation segregated for tiller number in a ratio of 1 to 1.47 and 1 to 0.36, respectively. Such ratios were poor fit to any monogenic ratios. The discrepancy of any genetic ratios may be understood in terms of cytoplasmic reasons of tillering characters of MET line as previously discusseed.

Table 3. Estimates of genetic parameters for ear-number.

Components	3-parameter model (weighted)	6-parameter model (unweighted)
m	1.59±0.05**	2.58±0.002**
d	0.71±0.04**	0.80±0.003**
h	-0.38±1.10**	-3.18±0.006**
i		-0.78±0.002**
j		-0.71±0.002**
k		1.88±0.004**
$X^2(2)$	32.83 (P<0.005)	Residual S.S.= 2.57E-7

**Significant at 1% level.

X^2 values for ear number of main stem were as high as 32.83 in 3 parameter model (Table 3). The parameters, m, d and h were all significant at 5% level. Weighted estimates of genetic effects in 6 parameter model couldn't be computed by computer because of too small error variance. Unweighted estimates were calculated instead. Residual S.S. was small as 2.57E-7. Gene action for ear number fitted to 6-parameter model. Dominance effect (h) and dominance x dominance (j) interactions were greater than additive effect (d) and additive x additive (i) and additive x dominance (k) interactions. It was then suggested that non-allelic interaction with duplicate type of cytoplasmic gene effects may be involved.

Estimates of Heritability

Heritability estimates in the broad sense were obtained for tiller and ear numbers (Table 4) and they were relatively small, less than 50%, probably due to small variance of F_2 generations.

Table 4. Heritabilities for number of tillers and ears per plant.

Number of tillers	44.47%
Number of ears	37.07%

Total Ear Weight of Each Plant

Total ear weight per plant was calculated in terms of total ear number weight index and compared among generations (Fig. 4). As shown in Fig. 4, the total ear number weight index of MET line was 2, while it was 1 in (MO17 x B68). The index was gradually decreased as the contribution of MET genotypes or cytoplasm decreased. The decrease of index was in the order of MET (P1), BC_{1-12}, F_2, F_1 and BC_{1-21}. It should be pointed out that the total ear number index, or simply ear weight per plant shouldn't be used as an indicator for kernel yield. For instance, the kernel yield of (MO17 x B68) which has low ear weight index was much higher than the MET line with high ear weight index. However, as long as the ear number weight index (total ear weight per plant) is compared among crosses involving MET line, the ear number weight was closely relalted with total kernel weight of tillers shown in Fig. 5. Fig. 5 shows kernel weight contribution of tillers to the total yield. As the number of tiller increased the kernel weight contribution of tillers also increased.

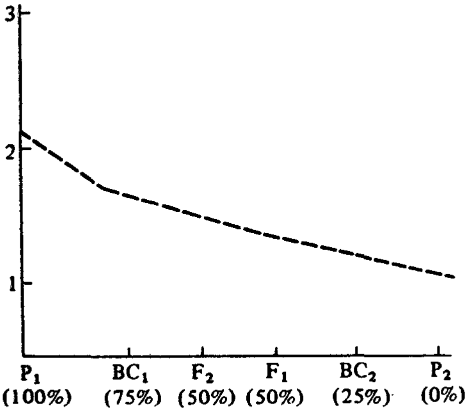

Fig. 4. Comparison of the total ear number weight index in each generation. Contribution of MET genotypes is in parenthesis.

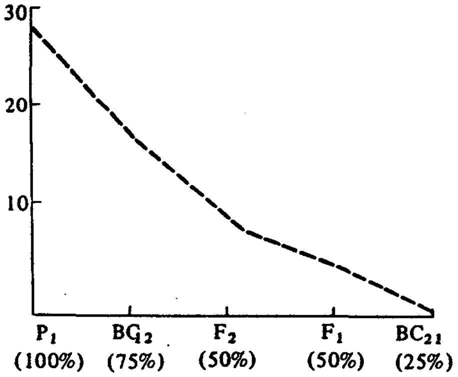

Fig. 5. Comparison of kernel yield from tillers in each generation. Contribution of MET genotypes is in parenthesis.

Barren Ears

Lonnquist(6) and Sorrell et al.(10) attempted to use prolificacy of maize to reduce the number of barren stalks when densely planted. The number of barren ears instead of barren stalks was observed among generations (Fig. 6). Percent of barren ears was increased as the MET cytoplasm decreased. Therefore, it is assumed that the number of ears and tillers and barreness are all major characters associated with MET line and these characters may be all cytoplasmically inherited.

Conclusion

Crosses of unrelated two maize lines revealed

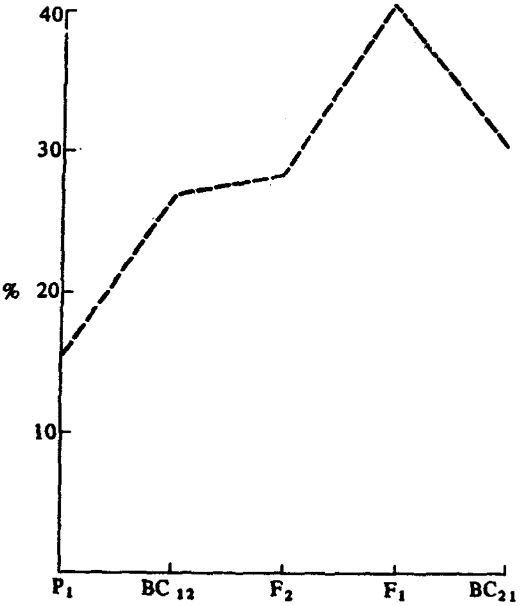

Fig. 6. Effects of MET cytoplasm on barren ears

very poor fit to qualitative inheritance of multi-ear and -tiller characters. The poor segregation in F_1's and in F_2's of the characters may be due to the masking effects of heterosis, manifested in crosses between unrelated two maize lines, on tiller and ear initiation. Tillers and ears appeared rather at backcross generation ($BC_{1\text{-}12}$), indicating the cytoplasmic effect or dosage effect of MET genotypes. From the study we could conclude that future studies should focus on accumulation of MET cytoplasm instead of simple progeny testing. Accumulation of MET cytoplasm can be accomplished by some backcross scheme using MET cytoplasm as female parent. Physiological studies on tiller and ear development of MET line under various environment are also required, since the characters of plants are all environment.

摘 要

1981年부터 崔 等이 在來種 옥수수의 蒐集種 가운데서 选拔한 한系統(MET)은 分蘖이 많이되고 또한 個體當 이삭(穗)數도 많아서 飼料用 옥수수의 育種材料로 價値가 있다고 생각되었으나 이 옥수수에 對한 遺傳的 分析이 確實히 되어 있지를 않았다. 따라서 本硏究에서는 MET와 非分蘖性이며 이삭도 하나 밖에 달리지 않는 水原 19號(Mo 17×B 68) 交雜種을 利用하여 F_1, F_2, BC_1, 世代를 養成하고 Mather의 世代平均分析法에 依하여 分析한 結果 MET系統의 多穗·多蘖性은 染色體上의 遺傳因子에 依한다기 보다 細胞質的 遺傳因子에 依한다는 것을 確認하였다. 이같은 結論은 MET系統을 母系로 하여 交雜한 戾交雜 世代에서 確實히 얻을 수가 있었다. 即 MET 系統을 母系로 利用했을 때의 平均分蘖과 이삭數는 MET를 父系로 利用했을 때의 分蘖數와 이삭數 보다 많았는데 이는 이같은 特性들이 母系遺傳을 하기 때문이다. 그러나 이같은 特性들이 F_1이나 F_2에서 나타나지 않은 것은 F_1에서 特히 보여주는 雜種強勢現象 때문에 옥수수의 頂部優勢性이 매우커서 相反的으로 分蘖이나 이삭의 發達이 抑制되었기 때문이라고 생각된다. 그리고 分蘖이나 이삭의 絕對數가 母系로 利用했던 MET에서 보다 雜種世代가 進展될수록 적어지는 것은 雜種強勢外에도 MET 系統의 細胞質的 내지 遺傳因子的 蓄積量(*Dose*)이 적어지기 때문이라고 생각되어진다. 이같은 MET系統의 特性은 戾交雜에 依한 MET系統의 細胞質을 維持하거나 蓄積하므로써 飼料用 옥수수의 育種에 利用될 수 있을 것으로 보여졌다.

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