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United States Patent [19]**Noble, Jr.**[11] **Patent Number:** **5,557,035**[45] **Date of Patent:** ***Sep. 17, 1996**[54] **HYBRID CORN PLANT & SEED (3489)**[75] **Inventor:** **Stephen W. Noble, Jr., Johnston, Iowa**[73] **Assignee:** **Pioneer Hi-Bred International, Inc.,
Des Moines, Iowa**[*] **Notice:** The term of this patent shall not extend beyond the expiration date of Pat. No. 5,444,178.[21] **Appl. No.:** **187,964**[22] **Filed:** **Jan. 28, 1994**[51] **Int. Cl.⁶** **A01H 1/02; A01H 4/00;
A01H 5/00; C12N 5/04**[52] **U.S. Cl.** **800/200; 800/250; 800/DIG. 56;
435/240.4; 435/240.47; 435/240.49; 435/240.5;
47/58; 47/DIG. 1**[58] **Field of Search** **800/200, 205,
800/235, 250, DIG. 56; 435/240.1, 240.4,
240.47, 240.49, 240.5; 47/58.01, 58.03,
58, DIG. 1**[56] **References Cited****U.S. PATENT DOCUMENTS**

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[57]

ABSTRACT

According to the invention, there is provided a hybrid corn plant, designated as 3489, produced by crossing two Pioneer Hi-Bred International, Inc. proprietary inbred corn lines. This invention thus relates to the hybrid seed 3489, the hybrid plant produced from the seed, and variants, mutants and trivial modifications of hybrid 3489.

10 Claims, 2 Drawing Sheets

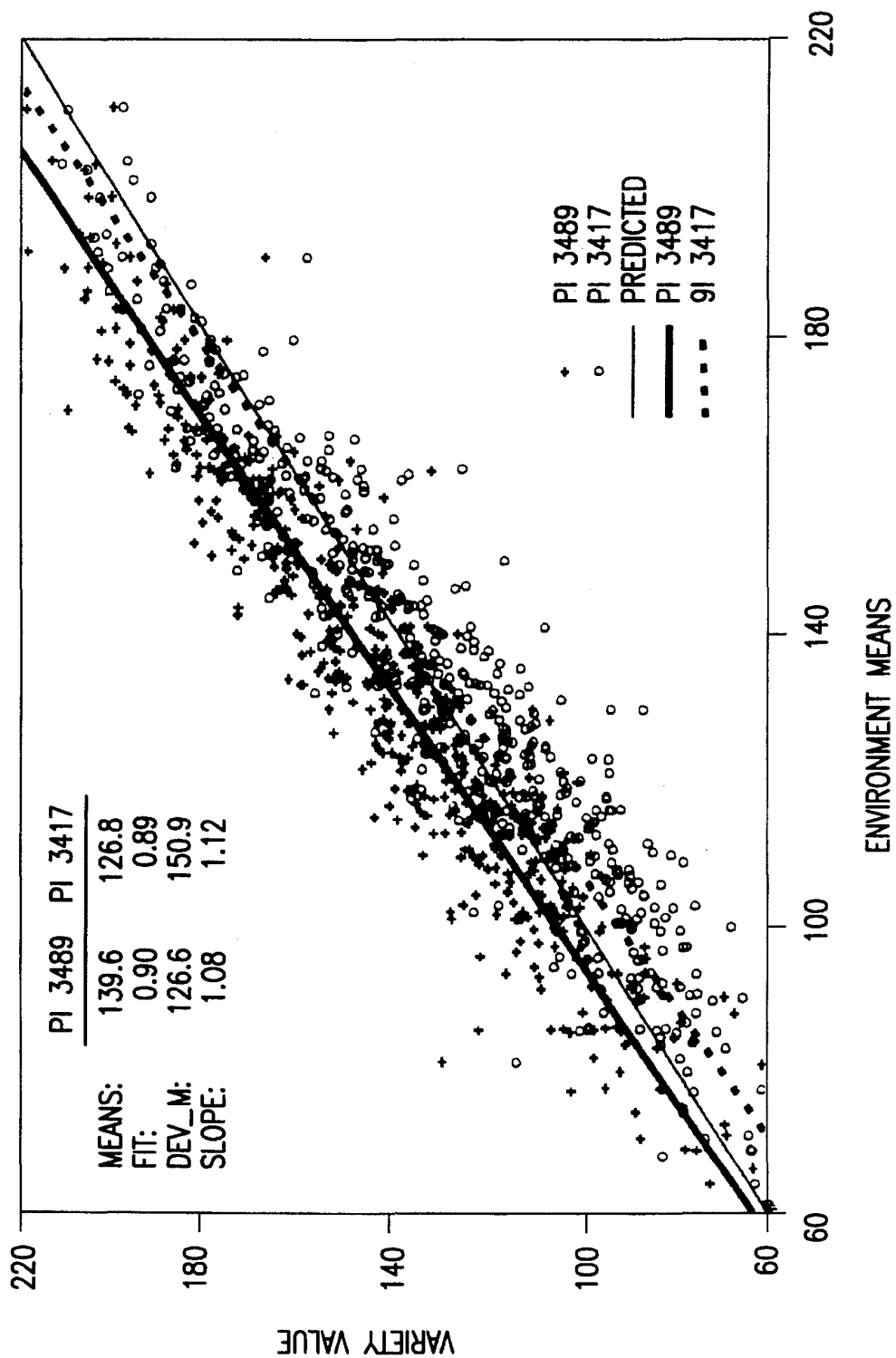


FIG. 1

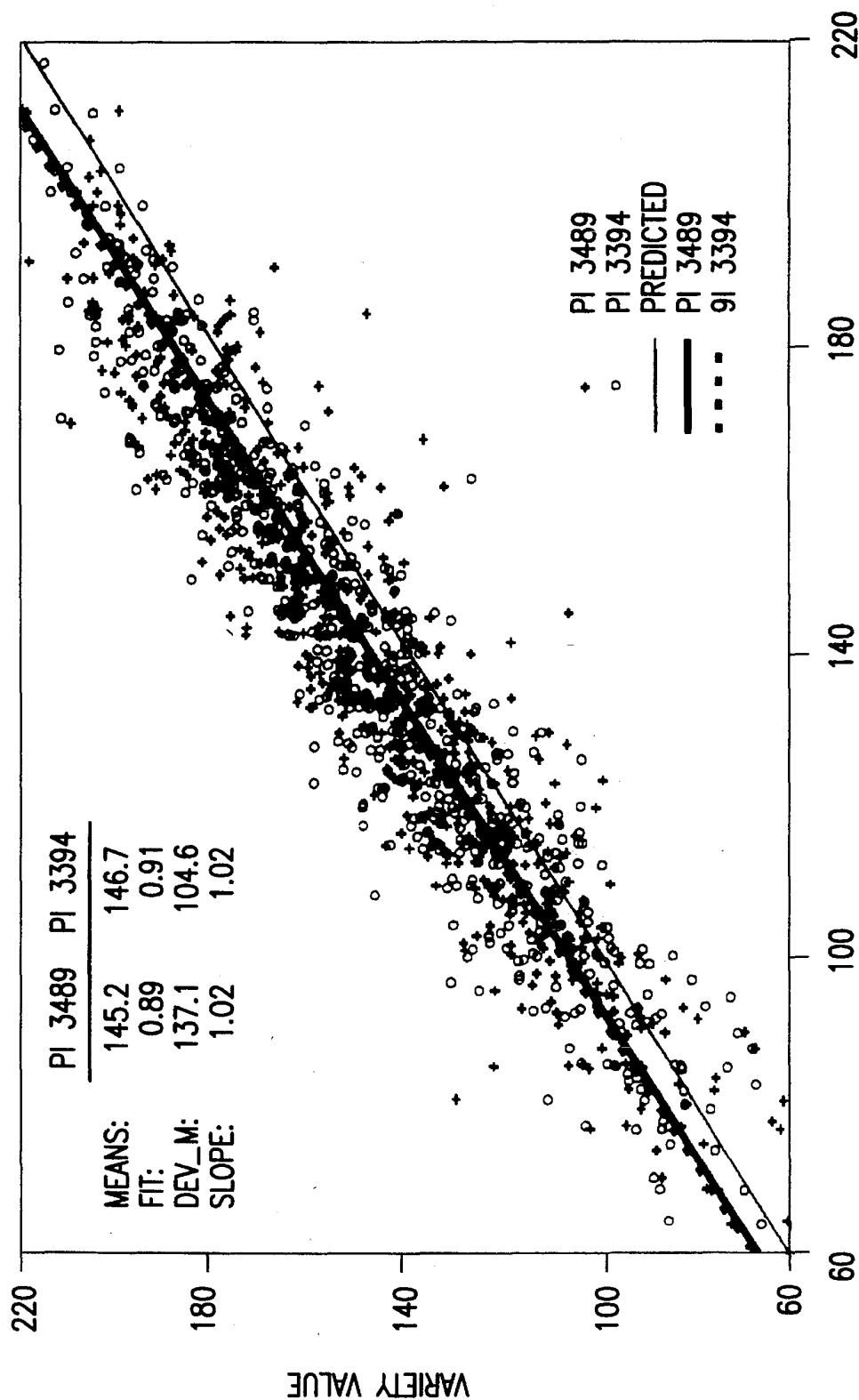


FIG.2

HYBRID CORN PLANT & SEED (3489)

FIELD OF THE INVENTION

This invention is in the field of corn breeding, specifically relating to a hybrid corn plant designated 3489.

BACKGROUND OF THE INVENTION

Plant Breeding

Field crops are bred through techniques that take advantage of the plant's method of pollination. A plant is self-pollinated if pollen from one flower is transferred to the same or another flower of the same plant. A plant is cross-pollinated if the pollen comes from a flower on a different plant.

Corn plants (*Zea mays* L.) can be bred by both self-pollination and cross-pollination techniques. Corn has separate male and female flowers on the same plant, located on the tassel and the ear, respectively. Natural pollination occurs in corn when wind blows pollen from the tassels to the silks that protrude from the tops of the incipient ears.

The development of a hybrid corn variety involves three steps: (1) the selection of plants from various germplasm pools; (2) the selfing of the selected plants for several generations to produce a series of inbred lines, which, although different from each other, breed true and are highly uniform; and (3) crossing the selected inbred lines with unrelated inbred lines to produce the hybrid progeny (F_1). During the inbreeding process in corn, the vigor of the lines decreases. Vigor is restored when two unrelated inbred lines are crossed to produce the hybrid progeny. An important consequence of the homozygosity and homogeneity of the inbred lines is that the hybrid between a defined pair of inbreds will always be the same. Once the inbreds that give a superior hybrid have been identified, the hybrid seed can be reproduced indefinitely as long as the homogeneity of the inbred parents is maintained.

Hybrid corn seed can be produced by manual detasseling. Alternate strips of two inbred varieties of corn are planted in a field, and the pollen-bearing tassels are removed from one of the inbreds (female). Providing that there is sufficient isolation from sources of foreign corn pollen, the ears of the detasseled inbred will be fertilized only from pollen from the other inbred (male), and the resulting seed is therefore hybrid and will form hybrid plants.

The laborious detasseling process can be avoided by using male-sterile inbreds. Plants of these inbreds are fertilized with pollen from another inbred that is not male-sterile. Pollen from the second inbred can contribute genes that make the hybrid plants male-fertile. Usually seed from detasseled normal corn and male sterile produced seed of the same hybrid is blended to insure that adequate pollen loads are available for fertilization when the hybrid plants are grown.

The objective of commercial maize hybrid line development programs is to develop new inbred lines to produce hybrids that combine to produce high grain yields and superior agronomic performance. The primary trait breeders seek is yield. However, other major agronomic traits are of importance in hybrid combination and have an impact on yield or otherwise provide superior performance in hybrid combinations. Such traits include percent grain moisture at harvest, relative maturity, resistance to stalk breakage, resistance to root lodging, grain quality, and disease and insect resistance. In addition the lines per se must have acceptable

performance for parental traits such as seed yields, kernel sizes, pollen production, all of which affect ability to provide parental lines in sufficient quantity and quality for hybridization. These traits have been shown to be under genetic control and many if not all of the traits are affected by multiple genes.

Pedigree Breeding

The pedigree method of breeding is the mostly widely used methodology for new hybrid line development.

In general terms this procedure consists of crossing two inbred lines to produce the non-segregating F_1 generation, and self pollination of the F_1 generation to produce the F_2 generation that segregates for all factors for which the inbred parents differ. An example of this process is set forth below. Variations of this generalized pedigree method are used, but all these variations produce a segregating generation which contains a range of variation for the traits of interest.

EXAMPLE 1

Hypothetical Example of Pedigree Breeding Program

Consider a cross between two inbred lines that differ for alleles at five loci.

The parental genotypes are:

Parent 1	A	b	C	d	e	F/A	b	C	d	e	F
Parent 2	a	B	c	D	E	f/a	B	c	D	E	f

the F_1 from a cross between these two parents is:

F_1	A	b	C	d	e	F/a	B	c	D	E	f
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Selfing F_1 will produce an F_2 generation including the following genotypes:

A	B	c	D	E	f/a	b	C	d	e	F
A	B	c	D	e	f/a	b	C	d	e	F
A	B	c	D	e	f/a	b	C	d	e	F

The number of genotypes in the F_2 is 3^6 for six segregating loci (729) and will produce $(2^6)-2$ possible new inbreds, (62 for six segregating loci).

Each inbred parent which is used in breeding crosses represents a unique combination of genes, and the combined effects of the genes define the performance of the inbred and its performance in hybrid combination. There is published evidence (Smith, O. S., J. S. C. Smith, S. L. Bowen, R. A. Tenborg and S. J. Wall, TAG 80:833-840 (1990)) that each of these lines are different and can be uniquely identified on the basis of genetically-controlled molecular markers.

It has been shown (Hallauer, Arnel R. and Miranda, J. B. Fo. *Quantitative Genetics in Maize Breeding*, Iowa State University Press, Ames Ia., 1981) that most traits of economic value in maize are under the genetic control of multiple genetic loci, and that there are a large number of unique combinations of these genes present in elite maize germplasm. If not, genetic progress using elite inbred lines would no longer be possible. Studies by Duvick and Russell (Duvick, D. N., *Maydica* 37:69-79, (1992); Russell, W. A., *Maydica* XXIX:375-390 (1983)) have shown that over the last 50 years the rate of genetic progress in commercial hybrids has been between 1 and 2% per year.

The number of genes affecting the trait of primary economic importance in maize, grain yield, has been estimated to be in the range of 10–1000. Inbred lines which are used as parents for breeding crosses differ in the number and combination of these genes. These factors make the plant breeder's task more difficult. Compounding this is evidence that no one line contains the favorable allele at all loci, and that different alleles have different economic values depending on the genetic background and field environment in which the hybrid is grown. Fifty years of breeding experience suggests that there are many genes affecting grain yield and each of these has a relatively small effect on this trait. The effects are small compared to breeders' ability to measure grain yield differences in evaluation trials. Therefore, the parents of the breeding cross must differ at several of these loci so that the genetic differences in the progeny will be large enough that breeders can develop a line that increases the economic worth of its hybrids over that of hybrids made with either parent.

If the number of loci segregating in a cross between two inbred lines is n , the number of unique genotypes in the F_2 generation is 3^n and the number of unique inbred lines from this cross is $\{(2^n) - 2\}$. Only a very limited number of these combinations are useful. Only about 1 in 10,000 of the progeny from F_2 's are commercially useful.

By way of example, if it is assumed that the number of segregating loci in F_2 is somewhere between 20 and 50, and that each parent is fixed for half the favorable alleles, it is then possible to calculate approximate probabilities of finding an inbred that has the favorable allele at $\{(n/2)+m\}$ loci, where $n/2$ is the number of favorable alleles in each of the parents and m is the number of additional favorable alleles in the new inbred. See Example 2 below. The number m is assumed to be greater than three because each allele has so small an effect that evaluation techniques are not sensitive enough to detect differences due to three or less favorable alleles. The probabilities in Example 2 are on the order of 10^{-5} or smaller and they are the probabilities that at least one genotype with $(n/2)+m$ favorable alleles will exist.

To put this in perspective the number of plants grown on 60 million acres (approximate U.S. corn acreage) at 25000 plants/acre is 1.5×10^{12} .

EXAMPLE 2

Probability of Finding an Inbred With m of n Favorable Alleles

Assume each parent has $n/2$ of the favorable alleles and only $1/2$ of the combinations of loci are economically useful.

no. of segregating loci (n)	no. favorable alleles in Parents ($n/2$)	no. additional favorable alleles in new inbred	Probability that genotype occurs*
20	10	14	3×10^{-5}
24	12	16	2×10^{-5}
28	14	18	1×10^{-5}
32	16	20	8×10^{-6}
36	18	22	5×10^{-6}
40	20	24	3×10^{-6}
44	22	26	2×10^{-6}
48	24	28	1×10^{-6}

*Probability that a useful combination exists, does not include the probability of identifying this combination if it does exist.

The possibility of having a usable high probability of being able to identify this genotype based on replicated field testing would be most likely smaller than this, and is a

function of how large a population of genotypes is tested and how testing resources are allocated in the testing program.

At Pioneer Hi-Bred International, a typical corn research station has a staff of four, and 20 acres of breeding nursery. Those researchers plant those 20 acres with 25,000 nursery rows, 15,000 yield test plots in 10–15 yield test sites, and one or two disease-screening nurseries. Employing a temporary crew of 20 to 30 pollinators, the station makes about 65,000 hand pollinations per growing season. Thus, one of the largest plant breeding programs in the world does not have a sufficiently large breeding population to be able to rely upon "playing the numbers" to obtain successful research results. Nevertheless, Pioneer's breeders at each station produce from three to ten new inbreds which are proposed for commercial use each year. Over the 32 Pioneer research stations in North America, this amounts to from about 100 to 300 new inbreds proposed for use, and less than 50 and more commonly less than 30 of these inbreds that actually satisfy the performance criteria for commercial use.

This is a result of plant breeders using their skills, experience, and intuitive ability to select inbreds having the necessary qualities so that improved hybrids may be produced.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a graph comparing the hybrid of this invention with commercial hybrid 3417 with respect to yield.

FIG. 2 is a graph comparing the hybrid of this invention with commercial hybrid 3394 with respect to yield.

SUMMARY OF THE INVENTION

According to the invention, there is provided a hybrid corn plant, designated as 3489, produced by crossing two Pioneer Hi-Bred International, Inc. proprietary inbred corn lines. This invention thus relates to the hybrid seed 3489, the hybrid plant produced from the seed, and variants, mutants and trivial modifications of hybrid 3489. 3489 is a very high yielding, widely adapted, stable 108 CRM hybrid. 3489 has above average yield across all environments.

DEFINITIONS

In the description and examples that follow, a number of terms are used herein. In order to provide a clear and consistent understanding of the specification and claims, including the scope to be given such terms, the following definitions are provided. ABS is in absolute terms and % MN is percent of the mean for the experiments in which the inbred or hybrid was grown.

BAR PLT=BARREN PLANTS. The percent of plants per plot that were not barren (lack ears).

BRT STK=BRITTLE STALKS. This is a measure of the stalk breakage near the time of pollination, and is an indication of whether a hybrid or inbred would snap or break near the time of flowering under severe winds. Data are presented as percentage of plants that did not snap.

BU ACR=YIELD (BUSHEL/ACRE). Actual yield of the grain at harvest in bushels per acre, adjusted to 15.5% moisture.

DRP EAR=DROPPED EARS. A measure of the number of dropped ears per plot and represents the percentage of plants that did not drop ears prior to harvest.

EAR HT=EAR HEIGHT. The ear height is a measure from the ground to the highest placed developed ear node attachment and is measured in inches.

EAR SZ=EAR SIZE. A 1 to 9 visual rating of ear size. The higher the rating the larger the ear size.

EST CNT=EARLY STAND COUNT. This is a measure of the stand establishment in the spring and represents the number of plants that emerge on a per plot basis for the inbred or hybrid.

GDU SHD=GDU TO SHED. The number of growing degree units (GDUs) or heat units required for an inbred line or hybrid to have approximately 50 percent of the plants shedding pollen and is measured from the time of planting. Growing degree units are calculated by the Barger Method, where the heat units for a 24-hour period are:

$$GDU = \frac{(\text{Max. temp.} + \text{Min. temp.})}{2} - 50$$

The highest maximum temperature used is 86° F. and the lowest minimum temperature used is 50° F. For each inbred or hybrid it takes a certain number of GDUs to reach various stages of plant development.

GDU SLK=GDU TO SILK. The number of growing degree units required for an inbred line or hybrid to have approximately 50 percent of the plants with silk emergence from time of planting. Growing degree units are calculated by the Barger Method as given in GDU SHD definition.

GRN APP=GRAIN APPEARANCE. This is a 1 to 9 rating for the general appearance of the shelled grain as it is harvested based on such factors as the color of the harvested grain, any mold on the grain, and any cracked grain. High scores indicate good grain quality.

MST=HARVEST MOISTURE. The moisture is the actual percentage moisture of the grain at harvest.

PLT HT=PLANT HEIGHT. This is a measure of the height of the plant from the ground to the tip of the tassel in inches.

POL SC=POLLEN SCORE. A 1 to 9 visual rating indicating the amount of pollen shed. The higher the score the more pollen shed.

POL WT=POLLEN WEIGHT. This is calculated by dry weight of tassels collected as shedding commences minus dry weight from similar tassels harvested after shedding is complete.

It should be understood that the inbred can, through routine manipulation of cytoplasmic factors, be produced in a cytoplasmic male-sterile form which is otherwise phenotypically identical to the male-fertile form.

PRM=PREDICTED RM. This trait, predicted relative maturity (RM), is based on the harvest moisture of the grain. The relative maturity rating is based on a known set of checks and utilizes standard linear regression analyses and is referred to as the Comparative Relative Maturity Rating System which is similar to the Minnesota Relative Maturity Rating System.

RT LDG=ROOT LODGING. Root lodging is the percentage of plants that do not root lodge; plants that lean from the vertical axis at an approximately 30° angle or greater would be counted as root lodged.

SCT GRN=SCATTER GRAIN. A 1 to 9 visual rating indicating the amount of scatter grain (lack of pollination or kernel abortion) on the ear. The higher the score the less scatter grain.

SDG VGR=SEEDLING VIGOR. This is the visual rating (1 to 9) of the amount of vegetative growth after emergence

at the seedling stage (approximately five leaves). A higher score indicates better vigor.

SEL IND=SELECTION INDEX. The selection index gives a single measure of the hybrid's worth based on information for up to five traits. A corn breeder may utilize his or her own set of traits for the selection index. One of the traits that is almost always included is yield. The selection index data presented in the tables represent the mean value averaged across testing stations.

STA GRN=STAY GREEN. Stay green is the measure of plant health near the time of black layer formation (physiological maturity). A high score indicates better late-season plant health.

STK CNT=NUMBER OF PLANTS. This is the final stand or number of plants per plot.

STK LDG=STALK LODGING. This is the percentage of plants that did not stalk lodge (stalk breakage) as measured by either natural lodging or pushing the stalks and determining the percentage of plants that break below the ear.

TAS BLS=TASSEL BLAST. A 1 to 9 visual rating was used to measure the degree of blasting (necrosis due to heat stress) of the tassel at time of flowering. A 1 would indicate a very high level of blasting at time of flowering, while a 9 would have no tassel blasting.

TAS SZ=TASSEL SIZE. A 1 to 9 visual rating was used to indicate the relative size of the tassel. The higher the rating the larger the tassel.

TAS WT=TASSEL WEIGHT. This is the average weight of a tassel (grams) just prior to pollen shed.

TEX EAR=EAR TEXTURE. A 1 to 9 visual rating was used to indicate the relative hardness (smoothness of crown) of mature grain. A 1 would be very soft (extreme dent) while a 9 would be very hard (flinty or very smooth crown).

TILLER=TILLERS. A count of the number of tillers per plot that could possibly shed pollen was taken. Data is given as percentage of tillers: number of tillers per plot divided by number of plants per plot.

TST WT=TEST WEIGHT (UNADJUSTED). The measure of the weight of the grain in pounds for a given volume (bushel).

TST WTA=TEST WEIGHT ADJUSTED. The measure of the weight of the grain in pounds for a given volume (bushel) adjusted for percent moisture.

YLD=YIELD. It is the same as BU ACR ABS.

YLD SC=YIELD SCORE. A 1 to 9 visual rating was used to give a relative rating for yield based on plot ear piles. The higher the rating the greater visual yield appearance.

MDM CPX=Maize Dwarf Mosaic Complex (MDMV=Maize Dwarf Mosaic Virus & MCDV=Maize Chlorotic Dwarf Virus): Visual rating (1-9 score) where a "1" is very susceptible and a "9" is very resistant.

SLF BLT=Southern Leaf Blight (*Bipolaris maydis*, *Helminthosporium maydis*): Visual rating (1-9 score) where a "1" is very susceptible and a "9" is very resistant.

NLF BLT=Northern Leaf Blight (*Exserohilum turcicum*, *H. turcicum*): Visual rating (1-9 score) where a "1" is very susceptible and a "9" is very resistant.

COM RST=Common Rust (*Puccinia sorghi*): Visual rating (1-9 score) where a "1" is very susceptible and a "9" is very resistant.

GLF SPT=Gray Leaf Spot (*Cercospora zeae-maydis*): Visual rating (1-9 score) where a "1" is very susceptible and a "9" is very resistant.

STW WLT=Stewart's Wilt (*Erwinia stewartii*): Visual rating (1-9 score) where a "1" is very susceptible and a "9" is very resistant.

HD SMT=Head Smut (*Sphacelotheca reiliana*): Percentage of plants that did not have infection.

EAR MLD=General Ear Mold: Visual rating (1–9 score) where a “1” is very susceptible and a “9” is very resistant. This is based on overall rating for ear mold of mature ears without determining specific mold organism, and may not be predictive for a specific ear mold.

ECB DPE=Dropped ears due to European Corn Borer (*Ostrinia nubilalis*): Percentage of plants that did not drop ears under second brood corn borer infestation.

ECB 2SC=European Corn Borer Second Brood (*Ostrinia nubilalis*): Visual rating (1–9 score) of post flowering damage due to infestation by European Corn Borer. A “1” is very susceptible and a “9” is very resistant.

ECB 1LF=European Corn Borer First Brood (*Ostrinia nubilalis*): Visual rating (1–9 score) of pre-flowering leaf feeding by European Corn Borer. A “1” is very susceptible and a “9” is very resistant.

DETAILED DESCRIPTION OF THE INVENTION

Pioneer Brand Hybrid 3489 has exceptional yield for its maturity. The hybrid is widely adapted and very stable which will make it an excellent companion hybrid to many of the hybrids in its area of adaptation.

Pioneer Brand Hybrid 3489 is a single cross, yellow endosperm, dent corn hybrid with exceptional yield in its maturity. It has had top yield for four straight years beginning with very early experimental topcross testing. Compared to the closest existing hybrid (3417), 3489 has resistance to brittle stalk, resistance to heavy infection of common rust, tolerance to less solar radiation and the ability to withstand excessive wet soil conditions. In addition, the high yield of 3489 is stable across environments.

This hybrid has the following characteristics based on the descriptive data collected primarily at Johnston, Ia.

VARIETY DESCRIPTION INFORMATION

HYBRID = 3489

Type: Dent

Region Best Adapted: Central Corn Belt

A. Maturity:

Minnesota Relative Maturity Rating (harvest moisture): 108

GDU's to Physiological Maturity (black layer): 2660

GDU's to 50% Silk: 1370

B. Plant Characteristics:

Plant height (to tassel tip): 284 cm

Length of top ear internode: 21 cm

Number of ears per stalk: Single

Ear height (to base of top ear): 80 cm

Number of tillers: None

Cytoplasm type: Normal

C. Leaf:

Color: (B14) Dark Green

Angle from Stalk: <30 degrees

Marginal Waves: (WF9) Few

Number of Leaves (mature plants): 21

Sheath Pubescence: (W22) Light

Longitudinal Creases: (PA11) Many

Length (Ear node leaf): 94 cm

Width (widest point, ear node leaf): 10 cm

D. Tassel:

Number lateral branches: 4

Branch Angle from central spike: >45 degrees

Pollen Shed: (KY21) Heavy

Peduncle Length (top leaf to basal branches): 28 cm

Anther Color: Pink

Glume Color: Green

E. Ear (Husked Ear Data Except When Stated Otherwise):

Length: 21 cm

Weight: 270 gm

Mid-point Diameter: 50 mm

Silk Color: Pink

Husk Extension (Harvest stage): Medium (Barely covering ear)

Husk Leaf: Long (>15 cm)

Taper of Ear: Slight

Position of Shank (dry husks): Horizontal

Kernel Rows: Straight Distinct Number = 16

TABLE 1C

VARIETY #1 - 3489 VARIETY #2 - 3394									
VAR #	BU		MST	* = 10% SIG		+ = 5% SIG		# = 1% SIG	
	ACR	ABS		PLT	EAR	SDG	EST	DRP	
		% MN	ABS	HT	HT	VGR	CNT	EAR	ABS
TOTAL SUM	1	155.3	106	23.5	107.5	41.2	5.9	56.1	99.8
	2	156.8	107	24.1	105.6	47.8	6.7	56.7	99.6
LOCS	563	563	577	313	312	228	356	280	
REPS	667	667	681	356	354	271	426	344	
DIFF	1.5	1	0.6	1.9	6.6	0.8	0.6	0.2	
PROB	.053*	.081*	.000#	.000#	.000#	.000#	.011+	.026+	
VAR #	GDU		TST	GRN		STK		BRT	
	SHD	SLK		APP	GRN	LDG	LDG	STK	ABS
		ABS	ABS	ABS	ABS	ABS	ABS	ABS	
TOTAL SUM	1	1342	1330	54.5	6.5	5.1	92.3	96.7	93.9
	2	1384	1346	54.7	6.6	6.3	95.2	97.1	94.5
LOCS	206	41	465	248	259	484	211	107	
REPS	233	43	551	291	308	568	264	122	
DIFF	42	16	0.3	0.1	1.2	2.8	0.3	0.6	
PROB	.000#	.000#	.000#	.228	.000#	.000#	.606	.333	

TABLE 1A-continued

DIFF	08	20	1.2	0.0	1.6	0.3	0.5	0.3
PROB	.000#	.000#	.000#	.660	.000#	.520	.458	.591

TABLE 1B

VARIETY #1 - 3489 VARIETY #2 - 3417									
VAR #	BU	BU	MST	PLT	EAR	SDG	EST	DRP	# = 1% SIG
	ACR	ACR		HT	HT	VGR	CNT	EAR	
	ABS	% MN	ABS	ABS	ABS	ABS	ABS	ABS	
	ABS	ABS	ABS	ABS	ABS	ABS	ABS	ABS	
TOTAL SUM	1	152.7	106	23.8	106.1	40.9	5.8	56.6	99.8
	2	140.0	96	24.3	99.0	38.6	5.3	57.6	99.9
LOCS	536	536	552	301	300	220	312	239	
REPS	629	629	645	335	333	255	354	288	
DIFF	12.7	10	0.5	7.1	2.3	0.5	1.0	0.1	
PROB	.000#	.000#	.000#	.000#	.000#	.000#	.000#	.914	
VAR #	GDU	GDU	TST	GRN	STA	STK	RT	BRT	# = 1% SIG
	SHD	SLK	WTA	APP	GRN	LDG	LDG	STK	
	ABS	ABS	ABS	ABS	ABS	ABS	ABS	ABS	
	ABS	ABS	ABS	ABS	ABS	ABS	ABS	ABS	
TOTAL SUM	1	1338	1331	54.3	6.3	5.3	93.1	97.0	94.1
	2	1321	1314	53.9	5.7	4.9	93.5Z	98.6	90.8
LOCS	185	42	449	224	234	464	210	111	
REPS	213	43	524	243	265	535	268	128	
DIFF	17	17	0.4	0.7	0.4	0.4	1.6	3.3	
PROB	.000#	.000#	.000#	.000#	.000#	.377	.002#	.000#	

Strip Test Data for Hybrid 3489

Comparison data was collected from strip tests that were grown by farmers. Each hybrid was grown in strips of 4, 6, 8, 12, etc. rows in fields depending on the size of the planter used. The data was collected from strip tests that had the hybrids in the same area and weighed. The moisture percentage was determined and bushels per acre was adjusted to 15.5 percent moisture. The number of comparisons represent the number of locations or replications for the two hybrids that were grown in the same field in close proximity and compared.

Comparison strip testing was done between Pioneer Brand Hybrid 3489 and Pioneer Brand Hybrids 3563, 3417 and 3394. The comparisons came from all the hybrid's adapted growing areas in the United States.

These results are presented in Table 2. 3489 shows a yield advantage over 3563 and 3417 and a yield disadvantage of 1.5 bushels per acre to 3394. 3489 has a moisture advantage over 3417 and 3394 but a disadvantage of 3563. 3489 showed a greater income advantage to the farmer based on adjusted growth income over 3563 and 3417 but a disadvantage of \$1.09 to 3394. Except for its small yield and income per acre disadvantage to 3394, 3489's yield and income advantage plus its advantage for other characteristics will make it an important addition for most of the areas where these hybrids are grown.

TABLE 2

PIONEER HYBRID 3489 VS PIONEER HYBRIDS 3563, 3417 AND 3394 FROM 1993 STRIP TESTS								
Brand	Product	Yield	Moist	Income /Acre	Pop K/Acre	Stand (%)	Roots (%)	Test Wt
PIONEER	3489	138.0	23.0	291.21	25.2	88	93	53.5
PIONEER	3563	128.3	19.9	277.76	25.5	85	92	55.3
Advantage		9.7	-3.1	13.45	-0.3	3	1	-1.8
Number of Comparisons		510	510	510	277	232	175	441
Percent Wins		81	4	70	35	52	9	5
Probability of Difference		99	99	99	96	99	92	99
PIONEER	3489	140.2	22.3	297.31	25.1	87	89	53.9
PIONEER	3417	127.6	22.5	269.93	25.6	88	90	53.3
Advantage		12.6	0.2	27.38	-0.5	-1	-1	0.6
Number of Comparisons		533	533	533	283	245	190	463
Percent Wins		91	57	91	35	39	6	58
Probability of Difference		99	99	99	98	25	34	99
PIONEER	3489	145.4	21.4	310.29	24.9	90	94	54.8

TABLE 2-continued

PIONEER HYBRID 3489 VS PIONEER HYBRIDS 3563, 3417 AND 3394 FROM 1993 STRIP TESTS								
Brand	Product	Yield	Moist	Income /Acre	Pop K/Acre	Stand (%)	Roots (%)	Test Wt
PIONEER	3394	146.9	22.3	311.38	25.1	92	94	55.0
Advantage		-1.5	0.9	-1.09	-0.2	-2	0	-0.2
Number of Comparisons		663	663	663	371	303	217	579
Percent Wins		43	64	47	36	28	9	28
Probability of Difference		99	99	66	94	99	74	99
PIONEER	3489	141.6	22.2	300.53	25.1	89	92	54.1
WEIGHTED AVG		135.3	21.6	288.38	25.4	89	92	54.6
Advantage		6.3	-0.6	12.15	-0.3	0	0	-0.5
Number of Comparisons		1706	1706	1706	931	780	582	1483
Percent Wins		69	44	68	35	38	8	31
Probability of Difference		99	99	99	99	16	15	99

Comparison of Key Characteristics for Hybrid 3489

Characteristics of Pioneer Brand Hybrid 3489 are compared to Pioneer Brand Hybrids 3563, 3417 and 3394 in Table 3. The ratings given for most of the traits are on a 1-9 basis. In these cases 9 would be outstanding, while 1 would be poor for the given characteristics. These values are based on performance of a given hybrid relative to other Pioneer commercial, precommercial and competitive hybrids that are grown in research and strip test trials. The traits characterized in Table 3 were defined previously and the ratings utilized not only research data but experience trained corn researchers had in the field as well as sales experience with the hybrids in strip tests and the field. These scores reflect the hybrid's relative performance to other hybrids for the characteristics listed. Table 3 shows 3489 yielded well for its maturity. 3489 has comparable grain appearance and brittle stalk resistance when compared to the other hybrids. 3489 has overall excellent yield and agronomic characteristics which should make it an important hybrid in its area of adaptation.

pollen, flowers, kernels, ears, cobs, leaves, husks, stalks, roots, root tips, anthers, silk and the like.

Duncan, Williams, Zehr, and Widholm, *Planta*, (1985) 165:322-332 reflects that 97% of the plants cultured which produced callus were capable of plant regeneration. Subsequent experiments with both inbreds and hybrids produced 91% regenerable callus which produced plants. In a further study in 1988, Songstad, Duncan & Widholm in *Plant Cell Reports* (1988), 7:262-265 reports several media additions which enhance regenerability of callus of two inbred lines. Other published reports also indicated that "nontraditional" tissues are capable of producing somatic embryogenesis and plant regeneration. K. P. Rao, et al., *Maize Genetics Cooperation Newsletter*, 60:64-65 (1986), refers to somatic embryogenesis from glume callus cultures and B. V. Conger, et al., *Plant Cell Reports*, 6: 345-347 (1987) indicates somatic embryogenesis from the tissue cultures of maize leaf segments. Thus, it is clear from the literature that the state of the art is such that these methods of obtaining plants are, and were, "conventional" in the sense that they are routinely used and have a very high rate of success.

TABLE 3

HYBRID COMPARISONS - CHARACTERISTICS Pioneer Hybrid 3489 vs Pioneer Hybrids 3563, 3417 and 3394										
HYBRID	SILK CRM	GDU SILK	BL CRM	GDU BL	CRM	YLD	H/ POP	L/ POP	D/D	S/L
3489	109	1390	109	2570	107	9	—	—	—	4
3563	106	1350	105	2660	103	8	8	7	5	6
3417	107	1370	110	2780	109	9	8	9	6	5
3394	111	1420	111	2800	110	9	9	9	5	7
HYBRID	R/L	STGR	D/T	T/WT	G/A	E/G	P/HT	E/HT	D/E	B/STK
3489	5	4	—	5	6	4	6	3	5	5
3563	6	6	7	7	7	4	7	4	7	5
3417	6	5	7	5	5	5	4	2	6	3
3394	7	8	8	5	5	8	5	5	5	5

INDUSTRIAL APPLICABILITY

This invention includes hybrid corn seed of 3489 and the hybrid corn plant produced therefrom. The foregoing was set forth by way of example and is not intended to limit the scope of the invention.

As used herein, the term plant includes plant cells, plant protoplasts, plant cell tissue cultures from which corn plants can be regenerated, plant calli, plant clumps, and plant cells that are intact in plants or parts of plants, such as embryos,

Tissue culture of corn is described in European Patent Application, publication 160,390, incorporated herein by reference. Corn tissue culture procedures are also described in Green and Rhodes, "Plant Regeneration in Tissue Culture of Maize," *Maize for Biological Research* (Plant Molecular Biology Association, Charlottesville, Va. 1982, at 367-372) and in Duncan, et al., "The Production of Callus Capable of Plant Regeneration from Immature Embryos of Numerous Zea Mays Genotypes," 165 *Planta* 322-332 (1985) Thus another aspect of this invention is to provide cells which

upon growth and differentiation produce corn plants having the genotype of 3489.

Corn is used as human food, livestock feed, and as raw material in industry. The food uses of corn, in addition to human consumption of corn kernels, include both products of dry- and wet-milling industries. The principal products of corn dry milling are grits, meal and flour. The corn wet-milling industry can provide corn starch, corn syrups, and dextrose for food use. Corn oil is recovered from corn germ, which is a by-product of both dry- and wet-milling industries.

Corn, including both grain and non-grain portions of the plant, is also used extensively as livestock feed, primarily for beef cattle, dairy cattle, hogs, and poultry.

Industrial uses of corn are mainly from corn starch in the wet-milling industry and corn flour in the dry-milling industry. The industrial applications of corn starch and flour are based on functional properties, such as viscosity, film formation, adhesive properties, and ability to suspend particles. The corn starch and flour have application in the paper and textile industries. Other industrial uses include applications in adhesives, building materials, foundry binders, laundry starches, explosives, oil-well muds, and other mining applications.

Plant parts other than the grain of corn are also used in industry. Stalks and husks are made into paper and wall-board and cobs are used for fuel and to make charcoal.

The seed of the hybrid corn plant and various parts of the hybrid corn plant can be utilized for human food, livestock feed, and as a raw material in industry.

Hybrid corn seed is produced by planting male and female parental lines in sufficient proximity to permit pollination of the female line by the male line ("pollinating proximity"). To assure genetic uniformity and avoid self-pollination, steps are taken to prevent pollen formation by the plants of the parental line chosen to serve as the female. This is most commonly done by manual detasseling. Alternate strips of the parental lines of corn are planted in a field, and the pollen-bearing tassels are physically removed from the female plants, either by hand or by machine. Providing that there is sufficient isolation from other sources of corn pollen, the ears of the female plants will be fertilized only by pollen from the male plants, and the resulting seed is therefore hybrid and will form hybrid plants. The seed is then harvested and conditioned, and then bagged or containerized for sale or storage. If desired, fungicides or other seed treatments can be applied prior to bagging or containerization. In a single-cross hybrid, both parents are inbred lines. In a double-cross hybrid, both parents are the F_1 offspring of a cross of two inbred lines. In a three-way cross, one of the parents is an inbred line and the other parent is an F_1 hybrid. Each cross is made in the manner described herein. Hybrid 3489, is a single cross hybrid, one parent of which is inbred line PHHB4, as described in the commonly assigned U.S. patent application of Stephen William Noble, Jr., Ser. No. 08/189,004, filed Jan. 24, 1994, now U.S. Pat. No. 5,444, 178, issued Aug. 22, 1995, the disclosures of which are hereby incorporated herein by reference, and the other is inbred line PHK56, as described in commonly assigned U.S. patent application No. 07/542,352, filed Jun. 20, 1990, now U.S. Pat. No. 5,347,081, issued Sep. 13, 1994, the disclosures of which are also hereby incorporated herein by reference.

Unfortunately, the manual detasseling process is not entirely reliable. Occasionally a female plant will be blown over by a storm and escape detasseling. Or, a detasseler will

not completely remove the tassel of the plant. In either event, the female plant will successfully shed pollen and some female plants will be self-pollinated. This will result in seed of the female inbred being harvested along with the hybrid seed which is normally produced.

Alternatively, the female inbred can be mechanically detasseled. Mechanical detasseling is approximately as reliable as manual detasseling, but is faster and less costly. However, most detasseling machines produce more damage to the plants than manual detasseling.

The laborious detasseling process can be avoided by using cytoplasmic male-sterile (CMS) inbreds. Plants of a CMS inbred are male sterile (do not form pollen) as a result of cytoplasmic factors resulting from the cytoplasmic, as distinguished from the nuclear, genome. Thus, this characteristic is inherited exclusively through the female parent, since the female parent provides the cytoplasm of the fertilized seed. CMS plants are fertilized with pollen from another inbred that is not male-sterile. Pollen from the male parent may or may not contribute genes that make the hybrid plants male-fertile. Usually seed from detasseled normal maize and CMS-produced seed of the same hybrid must be blended to insure that adequate pollen loads are available for fertilization when the hybrid plants are grown.

There can be other drawbacks to CMS. One is an historically observed association of a specific variant of CMS with susceptibility to certain crop diseases. This problem has led to widespread abandonment of use of that CMS variant in producing hybrid maize. In addition, CMS sometimes has a negative association with agronomic performance, particularly in the areas of stalk quality, early seedling vigor, and yield. Finally, CMS sometimes exhibits the potential for breakdown of sterility in certain environments, rendering CMS lines unreliable for hybrid seed production.

Another form of sterility, genetic male sterility, is disclosed in U.S. Pat. Nos. 4,654,465 and 4,727,219 to Brar et al. However, this form of genetic male sterility requires maintenance of multiple mutant genes at separate locations within the genome and requires a complex marker system to track the genes and make use of the system convenient.

Another form of male sterility is imparted in a manner by which expression of a transgene produces a "pollen-toxic" compound which blocks pollen formation in some manner.

Still another form of genetic male sterility uses an inducible promoter to regulate expression of a gene which is known to be critical in microsporogenesis, i.e., the production of pollen. The selected gene is cloned, its native promoter removed, and the modified gene is inserted into an expression sequence with an inducible promoter responsive to external control. Preferably, the promoter is one which responds to application of a specific non-phytotoxic chemical to the plant.

Using transformation and gene substitution, the "critical" gene is deleted from the genome of the plant and replaced by the genetically-engineered gene incorporated into the expression sequence with the inducible promoter. In this method, the inducible promoter is used to induce fertility, not sterility. The selected gene's promoter sequences are removed so that the gene is not transcribed and the plant is male sterile. When it is desired to increase the male-sterile plant, male fertility is restored by inducing expression of the critical gene with a specific non-phytotoxic chemical. Any of the foregoing methods and combinations thereof can be used to prevent pollen formation by the female parent of the hybrid.

Although the foregoing invention has been described in some detail by way of illustration and example for purposes

of clarity and understanding, it will be obvious that certain changes and modifications may be practiced within the scope of the invention, as limited only by the scope of the appended claims.

What is claimed is:

1. Seed of maize hybrid 3489.
2. A plant produced by the seed of claim 1.
3. A culture of regenerable cells or protoplasts of a plant produced from seed of maize hybrid 3489, wherein the culture regenerates plants having all of the physiological and morphological characteristics of maize hybrid 3489.
4. A culture according to claim 3, wherein the cells or protoplasts are from a tissue selected from the group consisting of leaves, pollen, embryos, roots, root tips, anthers, silks, flowers, kernels, ears, cobs, husks and stalks.
5. A corn plant regenerated from a culture of cells or protoplasts of a plant produced from seed of maize hybrid 3489, and having all of the physiological and morphological characteristics of maize hybrid 3489.

6. A method of making a segregating population of F_2 plants, comprising the step of self-fertilizing a plant according to claim 2 and harvesting and planting the resultant seed.

7. A segregating population of F_2 plants made by the method of claim 6.

8. A method of making a segregating population of F_2 plants, comprising the steps of crossing a plant of maize hybrid 3489 with another plant of maize hybrid 3489 and harvesting and planting the resultant seed.

9. A segregating population of F_2 plants made by the method of claim 8.

10. A method of making a three-way maize hybrid, comprising the step of crossing a hybrid plant according to claim 2 with a plant of an inbred line of maize.

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