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Review article

SELECTION ON UNIFORMITY AND YIELD STABILITY IN MAIZE

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Abstract: Historically speaking, both the introduction of double-cross hybrids and use of single crosses have caused the increase in grain yield and significantly improved agricultural practice. Nowadays, the uniformity of crops is regarded as an advantage of modern agriculture, since the uniformity of products is crucial in global market. Thus, uniformity of crop maturation provides both planning and efficient mechanized harvest. F_1 single-cross hybrids of maize, which is an allogamous species, not only exploit heterosis, but also impose homogeneity. Basically, the uniformity of hybrids has been regarded as their crucial advantage. There are two aspects of hybrid maize uniformity: (*i*) genetic homogeneity and (*ii*) genetic stability. Genetic homogeneity refers to presence of identical genotypes, whereas genetic stability refers to phenotypic uniformity (homeostasis) in different environments. At present, yield performance of inbreds has not advanced as rapidly as performance of hybrids, especially in stressful environments. Focusing on inbred productivity combined with stability may be more appropriate strategy in the future. Poor farmers are not able to employ superior genotypes because they require considerable financial investment, and farmers survive not due to high yield in good seasons, but due to enduring extreme ones. Breeding process may create genotypes in favourable seasons when genetic variance is maximal and environmental influence is minimal, which should be followed by breeding for different environments. The aim of such breeding are, most probably, genotypes intended for a specific set of conditions which, in fact, represents a convergence of two strategies of plant breeding. One

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should probably bear in mind the strategy of both yield improvement and survival of farmers in exreme conditions, without decreasing yield of best genotypes, especially those adapted only to favorable conditions. Solution to this problem should be: financial (best possible loans), social (education), and technological (breeding improved genotypes and advanced agricultural production).

Key words: maize, uniformity, heterosis, stability, homogeneity, selection, inbreeding, hybrids.

Genetic homogeneity

Breeding of F_1 hybrids of maize is successful because it both exploits heterosis and increases homogeneity. The uniformity of hybrids is consisted of: (*i*) genetic homogeneity (Živanović et al., 1994) and (*ii*) genetic stability. Genetic homogeneity is focused on maintenance of the identity of genotypes (Živanović and Šurlan-Momirović), while genetic stability tends to maintain phenotypic uniformity (homeostasis) in different environments (Živanović et al., 1998).

Phenotypic homogeneity is achieved by different methods, such as vegetative propagation and various breeding methods (Živanović 1997; Živanović et al., 1998). Vegetative propagation is multiplication of plants via mitosis and differentiation of plant tissues. This technique is applied to allogamous plants wich possess heterozygous genotypes and segregate in each generation. Heterozygous genotypes are multiplied by different cell or tissue culture techniques (androgenesis, somatic embryogenesis, organogenesis, etc.). Genetic homogeneity in heterozygous genotypes can be obtained by apomixes which is a type of vegetative propagation and results in developing seeds without prior fertilization. Virus-free plants can be derived by apomixes. Apomixes is genetically controlled and is used in propagation of heterozygous genotypes.

Breeding techniques

Massive seed production in maize is possible due to diferent breeding methods which provide homozygosis of important morphological traits and, simultaneously, maintain heterozygosis in order to avoid inbreeding depression. On the other hand, relative uniformity in autochtonous and introduced populations can be acheived by mass selection of a number of traits after several generations. Combination of pedigree and mass selection is also succesful in achieving uniformity with respect to certain agronomical traits in allogamous species (Živanović, 1993; 1997a). Maize breeding, essentially, includes: i) obtaining inbred lines and ii) obtaining heterozygous hybrids. The two aspects are opposed to one another and, yet, represent a whole of a maize breeding program.

Inbreeding

Homogeneity of heterozygous genotypes is increased by inbreeding. However, the consequnce of inbreeding is inbreeding depression wich is expressed as a decrease in yield and difficult cultivation of such plants. Much as such inbreds are genetically homogenous, they frequently express a considerable variability in certain morphological traits, despite the phenomenon of morphological uniformity (Živanović, 1997). A number of reports indicate that variability in inbred lines is larger than in F_1 hybrids and populations regarding certain traits (table 1). Why variability in inbreds is larger than in hybrids is not easy to explain. It is not genetic variability, since inbred plants are during five to six generations. This kind of variability is a consequence of general ecological variability (*VEg*) and specific ecological variability (*VEs*) (Živanović, 1997, 1997a; Šurlan-Momirović et al., 2000). General ecological variability (*VEg*) is a result of all environmental factors, while specific ecological variability (*VEs*) is caused by the action of plant organs during its development (Falconer, 1989). Variability caused by plant development is larger in quantitative traits during organogenesis. Jugenheiner (1976) studied five traits in maize inbreds (homozygous) and various heterozygous acquisitions. The smallest variability was expressed by inbreds with respect to the number of kernels in a row which is, most probably, determined in early developmental stages. Variability of other traits was expressed to a greater extent because of stronger influence of specific and general ecological variability. Uniformity of yield in inbreds was increased during subsequent cycles of selection. It can be concluded that genetic homogeneity of non-adapted material is unstable unless it is associated with breeding which tends to introduce adaptation genes (Janick, 1999).

Tab. 1. - Yield performance and uniformity of various types of hybrids, including inbred lines Hy, L317, WF9 and 38-11 (adapted from Jugenheimer, 1976)

Hybrid type	Yield (t/ha)	Ear weight (%)	Ear length (%)	Ear circu-mference (%)	No kernel/ row (%)	Ear height (%)
4 inbred lines	2.57	105	156	122	102	160
6 single-crosses	6.57	100	100	100	100	100
12 three-way-crosses	6.26	106	109	115	108	126
12 single-backcrosses	6.40	403	109	116	122	133
12 backcrosses	6.57	101	114	115	129	136
3 double crosses	6.16	120	120	131	138	140
6 top-crosses	6.08	110	121	120	132	186
1 open-pollination cv.(op)	5.73	117	130	127	149	178

CVF_1=100

Production of F_1 hybrids

Heterozygous F_1 hybrids are derived by hybridization of different inbred lines. This breeding technique provides uniformity in seed production in allogamous species, because open-pollinating populations consist of mixture of different genotypes. Genetic homogeneity, combined with high degree of heterosis can be obtained by selection within and among inbreds. Genetic variability in F_1 hybrids depends on homozygous parents (Šurlan-Momirović et al., 1996; Todorović et. al., 1997, Todorović et al., 1997a). The following formula (table 2) can be applied to a given population in equilibrium (gene frequency is 0.5):

T a b. 2. - Percentage of random crosses that are complementary non-segregating, following self-fertilization for n segregations with m pairs of factors and gene frequency of 0.5

		No. Factor pairs					
Self generation	Segreg. generation	1	2	3	5	10	m
S_0	1	25.00	6.25	1.56	0.10	0.00	$(1/4)^m$
S_1	2	56.25	31.64	17.80	20.14	0.32	$(9/16)^m$
S_2	3	76.56	58.62	44.88	20.14	6.92	$(49/64)^m$
S_4	5	93.85	88.07	82.65	72.80	52.99	$(961/1024)^m$
S_{n-1}	n	$((2^n-1)/2^n)^2$	$((2^n-1)/2^n)^3$	$((2^n-1)/2^n)^4$	$((2^n-1)/2^n)^6$	$((2^n-1)/2^n)^{11}$	$((2^n-1)/2^n)^{m+1}$

n – number of segregating generations; *m* – number of gene pairs in which parents differ.

Homogeneity of inbreds is increased from one selfing generation to the next. Thus, a decrease in heterozygosis of 50% per selfing generation is expected. The level of heterozygosis can be higher than expected for the following reasons: (*i*) natural selection favors heterozygotes, (*ii*) random mating and (*iii*) mutations.

F_1 hybrids can be derived by different methods of crossing inbred lines. Differences in both grain yield and the level of heterosis arise as the consequence of those different methods. Obtaining maize hybrids is somewhat easier due to the exploitation of cytoplasmic male sterility.

T a b. 3. - Types of hybrids based on the number of parental inbred lines

Type of hybrids	Pedigree
Top – crosses	A x op cultivar, or (A x B) x op cultivar
Single crosses	(A x B)
Modified single crosses	((A x A') x B)
Sister line crosses	(A x A') x (B x B')
Three – way crosses	(A x B) x C
Modified three-way crosses	(A x B) x (C x C')
Double crosses	(A x B) x (C x D)
Double backcrosses	((A x A) x A) x ((C x D) x C)
Single backcrosses	(A x B) x ((C x D) x C)
Multiple crosses	((A x B) x (C x D)) ((E x F) x (G x H))
Synthetics and composites	A number of lines

Phenotypic uniformity of inbreds is increased by the application of different methods of selection, whereas F_1 hybrids, derived by different multiple crossings (top-cross, three-way cross, etc.) express higher level of genetic variability than single cross hybrids (table 3). All the above mentioned systems of crossing expand genetic variability in the progeny compared to single-crosses, but, on the other hand, tend to reduce heterosis.

Genetic adaptability and stability

Adaptability (adaptation to environmental factors) of a given cultivar or hybrid is mostly defined as inherent genetic ability of a cultivar to perform stable and high yield in various environments. The level of yield depends on genetic yield potential (all favourable genes incorporated into a cultivar during a breeding process). Stability of yield or of any other trait depends on the ability of a given cultivar to react to changes in the enviroment, which is also referred to as phenotypic plasticy (Frey, 1983). This phenomenon is conditioned by genetic constitution of a cultivar i.e. by the reaction of its genotypes as individuals and a population as a whole. The point is, actually, in cultivar / environment interaction whose intensity depends on genetic constitution of a cultivar and on the intensity of certain limitating environmental conditions. The outcome of the cultivar /environment interaction reflects on both the adaptability and stability of a cultivar (Borojević, 1992).

Hybrid cultivar is genetically unique concerning both adaptability and stability of yield. Hybrid cultivar is genetically homogeneous, because all individuals (plants) are uniform, but, at the same time, are heterozygous. Hybrid cultivar actually does not possess genetic variability, but opposite to inbred, it is completely heterozygous which accounts for its extremely developed physiological homeostasis. That is why hybrids have high yield genetic potential and show high adaptability and stability of yield and other traits in different environments.

In case of maize with a history of double crosses (*DC*) previously and, almost exclusively, single crosses (*SC*) currently, modern double crosses proved to express somewhat lower yield but higher adaptability and stability of yield than single cross hybrids in different environments. However, there are studies which indicate very good adaptability and stability of single crosses, and, also, their better reaction to improved growing conditions. These results are certainly important, bearing in mind the choice of suitable hybrids in specific agroecological areas.

Genetic stability – homeostasis – indicates lower level of genotype/environment interaction (*G x E*) and also weaker reaction to environmental changes, especially to stress. When a large number of inbreds, clones, or hybrids is tested during a number of years or locations per year, different rank of traits is obtained. Changes in rank or relative differences in locations are statistically defined as *G x E* interaction. As a consequence of different response to stress, environmental factors may include abiotic (high temperatures, photoperiod, insolation, soil humidity, duration of growing season, soil quality, and growing technology) and biotic factors (crop density, response to viruses, bacteria, nematodes, fungi, arthropodes, etc.). Principal limiting abiotic factors in Serbia and Montenegro are high temperature and low relative air humidity during pollination period. This is confirmed by studies in the USA (Janick, 1999). An ideal hybrid should constantly perform above-average yield, especially in stress conditions, if it is to be widely used.

Populations of allogamous species possess genetic stability and genetic heterogeneity that creates population allevation. Population alleviation is inevitably reduced in a homogenous single-cross which is consisted of *SC* genotypes. Therefore, there is a dilemma in hybrid breeding strategies. Namely, maximal yield (maximal heterosis) is expected in *SC* F_1 hybrids, but uniformity of F_1 hybrids precludes population allevation. However, genetic stability is a heritable trait and, as such, it may be incorporated by heterotic combining (Eberhart and Russel, 1966; Russel and Eberhart, 1968; Eberhart, 1969). Moreover, population alleviation for yield can be exploited in more or less extreme conditions. Breeding of high-yielding and highly stable single crosses in high density proved to have been the best way of continuous improvement of yield in the USA and Serbia and Montenegro since the 60s and the 70s. Duvick (1984, 1997) showed that best modern single- cross hybrids did not express higher average yield than best hybrids in previous periods, in low density. While tending to improve yield, a breeder must take into account the improvement of stress tolerance, especially the ability of enduring high level of stress caused by high crop density (table 5).

Stability

Adaptability and stability of hybrids can be measured though regression coefficient of yield of each hybrid in relation to average yield of all hybrids in each tested location. A hybrid is regarded as stable if it performs high average yield, regression coefficient approximately 1 and as small deviation as possible (Živanović, 1993, 1997a).

Genetic stability can also be estimated by other analytical parameters. Thus, Becker (1981) claimed that, according to biological concept, stable genotypes should exhibit minimal variance in different environments. According to agricultural concept, stable genotypes are those which show minimal interaction with the environment. This interaction is defined as ecovalence (Wricke, 1964;

Eberhart, 1966). Analyzing these two concepts, it can be concluded that the yield regression method in different environments in relation to mean value of all genotypes is widely used method, that those two values are combined, because regression coefficiens are in almost perfect correlation with the variances, and that mean squares of deviation from regression are highly correlated with the ecovalence (Wricke, 1964; Eberhart, 1969; Živanović, 1993, 1997a).

Tab. 4. - The regression coefficient (b) indicates gain for the US
(Adapted from Janick, 1999)

	Genotype		
	Open pollinated	Double – cross	Single - cross
B	0.02	1.04	1.71

Tab. 5. - Average grain yield in hybrids at different breeding periods
(Adapted from Ivanović et al., 1995)

Hybrid	G1	G2	G3	Mean
ZPSC 4	8.251	9.264	9.597	9.037
NSSC 70	7.296	7.895	8.363	7.851
ZPSC 6	7.077	7.483	8.127	7.562
ZPSC 1	6.771	7.287	7.748	7.269
ZPSC 3	6.522	6.639	7.179	6.780
ZPSC 704	7.771	8.861	9.631	8.754
ZPSC 670	7.969	8.715	9.552	8.746
ZPSC 603	6.774	7.467	8.234	7.491
ZPSC 677	10.101	11.943	12.578	11.541
ZPSC 539	7.310	8.425	8.970	8.235
Mean	7.584	8.398	8.998	8.327

$LSD_{0.05}$- for densities = 0.136;
$LSD_{0.01}$- for densities = 0.179
G1 = 40,000 plants per hectare,
G2 = 50,000 plants per hectare,
G3 = 60,000 plants per hectare.

$LSD_{0.05}$- for hybrids = 0.249
$LSD_{0.01}$- for hybrids = 0.327
$LSD_{0.05}$- for G x H = 0.431
$LSD_{0.01}$- for G x H = 0.566
H = hybrid

If a genotype is to be considered stable, it must fulfill the following requirements: (*i*) small ecovalence, (*ii*) ist reaction to the environment must be equal to the reaction of all the other genotypes in the experiment, and (*iii*) residual mean square of regression to ecological index must be small (Janick, 1999).

Eberhart (1969) developed a procedure of determining yield stability in hybrids, which is performed by comparative trials set on a number of locations or years. The model is based on calculating linear regression for each genotype in relation to the environment (bi) and deviation from regression (s^2_{di}). Theoretically, most stable are those genotypes in case of which $bi = 1$ and $s^2_{di} = 0$. Genotypes with $bi > 1$ react better to improved growing conditions, while genotypes with $bi < 1$ react better to less favourable growing conditions.

Estimates in single- and double- crosses indicate their genetic differences in yield stability (tab. 6). On the basis of a diallel set of ten inbreds, Eberhart and Russell (1966, 1969) came to the conclusion that additive genes act in expression of yield stability. Stable hybrids can be created by crossing stable inbreds, because there is positive correlation between stability and yield.

Tab. 6. - Stability parameters ($bi\ i\ s^2_{di}$) of grain yield in hybrids at different breeding periods (Adapted from Ivanović,et al., 1995)

Hybrid	G1		G2		G3	
	bi	s^2_{di}	bi	s^2_{di}	bi	s^2_{di}
ZPSC 4	0.69**	1.00*	0.76	0.96**	0.66**	1.45**
NSSC 70	0.89	0.01	0.95	0.15	0.96	-0.06
ZPSC 6	0.98	-0.01	0.99	0.32*	1.02	0.33*
ZPSC 1	0.86	0.57**	0.79	0.51**	0.73*	0.88**
ZPSC 3	1.05	0.13	1.00	0.15	1.05	-0.07
ZPSC 704	1.04	0.45**	1.09	0.48**	1.11	0.31*
ZPSC 670	1.14	0.47**	1.27*	0.05	1.23	0.11
ZPSC 603	1.23	0.44**	1.18	0.51**	1.21	0.26*
ZPSC 677	0.93	1.19**	0.86	1.73**	0.85	1.64**
ZPSC 539	1.14	0.28**	1.09	0.19	1.16	0.08

$LSD_{0.05}$- *; $LSD_{0.01}$- **
G1 = 40,000 plants per hectare,
G2 = 50,000 plants per hectare,
G3 = 60,000 plants per hectare.

A strategy that provides maximal genetic improvement in maize yield must include simultaneous breeding for yield and stability, starting from initial segregating generations. Fasoulas and Fasoulas (1997a, 1997b) set the rules which should be obeyed in order to fulfill the above-mentioned requirements. Breeding of individual plants should be conducted in similar environments, because the phenotype is maximally expressed and there is an increase in heritability of target traits. High selection pressure may increase gene frequency through selfing or crossing. New genotypes should be tested at a number of locations with replications, according to a standardized experimental design (Fasoulas and Fasoulas, 1995). Thus, each hybrid will express its traits and its identity in a given environment and specific technology.

The criterion of breeding should be a combination of yield genetic potential and stability (phenotypic standard deviation). After Fasoulas and Fasoulas (1995) the predicted criterion (PC) for breeding of all types of cultivars is: $PC = x(x_s - x)s^2_p$, where x is average yield of a genotype prior to breeding; x_s is average yield of genotypes obtained by breeding; s^2_p is the phenotypic variance of genotypes obtained by breeding. The *PC* parameter is similar to Falconer's general equation of response to selection *(R)*: $R = s^2_g(x_s - x)s^2_p$. where x is substituted by genetic variance, s^2_g. This is possible when both genetic and phenotypic variance are maximal, and also when the difference in average performance of the initial and created genotype is maximal. Therefore, it is necessary to start breeding process in initial segregating generations (Fasoulas and Fasoulas, 1997b; Janick, 1999).

Strategy for achieving uniformity and stability

Modern maize industry worldwide and to a certain extent in Serbia and Montenegro continually requires new single-cross hybrids in order to gain maximal yield and to increase uniformity. Double-cross hybrids were used at the beginning of modern mass production, and later they were replaced by single-cross hybrids. Thus, the stress was given to an increase in average yield, while yield stability received less attention. Currently, it is more important to introduce stable *SC*s which are highly productive in high density than to improve yield in new inbreds. This is possible by testing a large number of single-crosses on a number of locations, paying attention to genetic improvement of hybrids and combining abilities. Although stability is a heritable trait, direct breeding for it is rarely performed. However, indirect effects, based on single-crosses evaluation, are taken into account. Inbred stability may be estimated by analyzing their single crosses in a diallel set. Consequently, the number of inbreds is much smaller than that of their hybrids. Therefore, direct breeding of inbreds may be an efficient procedure. Nowadays, both yield and quantity of new inbred lines are not increased as rapidly as productivity and quantity of hybrids obtained by their crossing (Meghji et al., 1984), especially in stressful environments (Janick, 1999). Concentrating efforts on both productivity and stability of inbred lines may well prove to be an important strategy.

Uniformity and stability in maintaining Serbian agriculture

From all that was stated above, it can be inferred that hybrids may not be the best solution possible to the maintainance of poor farmers in Yugoslavia and other undeveloped countries for at least two reasons: (*i*) they require considerable investment in seed production and technology, and (*ii*) there is justifiable concern that growing non-adapted hybrids may reduce diversity of maize (Živanović, 1993, 1997a; Živanović and Momirović, 2000).

Considerably high prices of seed raise production costs and eventually the market price of the final product through the price of seed and high imputs of growing such genotypes. The risk of growing non-adapted genotypes is minimal, because each breeding company conducts extensive trials at numerous locations. Thus, clear climatic distribution of hybrids is possible.

Above all, modern hybrids are inferior in stability to autochtonous populations. Ceccareli and Grando (1996) claim that inbred lines may be suitable in a stressful environment. According to these authors, in well organized maize production, new hybrids are superior to local varieties and populations, but the case is reverse in extremely unfavorable conditions. Moreover, poor farmers in extreme conditions maintain genetic diversity of different species and also heterogeneity of cultivars adapted to a specific environment. Actually, poor farmers survive not due to high yield in good seasons, but due to enduring extreme ones. Failure of new hybrids in extremely unfavourable conditions, based on one stable and one unstable hybrid, is shown in Figure 1. Still, according to these authors, local populations, when exposed to high selection pressure, in stressful environment, may be genetically improved in adaptation to unfavorable conditions. This is important for incorporation of genes responsible for individual alleviation of stress in inbreds and hybrids.

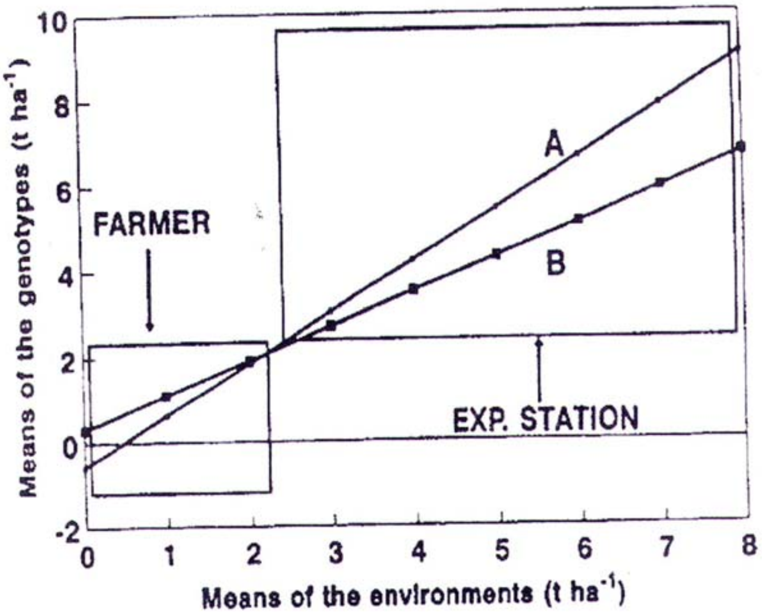

Fig. 1. – Failure of new hybrids under extremely unfavorable conditions, on the basis of one stable and one unstable hybrid (adapted from Janick, 1999)

Maintaining continuance in stable progeny of a stable donor is important for breeding process. This progeny may be created by breeding in favourable seasons when genetic variance is maximal and environmental influence is minimal, which should be followed by breeding for different environments. The aim of such breeding are, most probably, genotypes intended for a specific set of conditions. This, in fact, represents a convergence of two strategies of plant breeding, or, as Falconer (1952) paraphrased "a given improvement A by breeding in the environment A". New genotypes should be tested in a target environment i.e. location.

One should probably bear in mind a strategy of both yield improvement and survival of farmers in extreme conditions, without decreasing yield of best genotypes, especially those adapted only to favorable conditions. This strategy should be based on simultaneous improving of both the circumstances in which agricultural production is set and agricultural production itself. Poor farmers are not able to employ superior genotypes in extreme conditions due to apparently unbreachable world poverty. Solution to this problem should be: financial (best possible loans), social (education), and technological (breeding improved genotypes and advanced agricultural production).

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SELEKCIJA NA UNIFORMNOST I STABILNOST PRINOSA KUKURUZA

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Rezime

Uniformnost useva se smatra poželjnom osobinom u modernoj poljoprivredi, jer je proizvod uniformnosti esencijalan na tržištu. Uniformnost u sazrevanju omogućuje planiranje biljne proizvodnje i efikasnu mehaničku žetvu i berbu. Osim toga, uniformnost useva je bitna za maksimalni prinos. Obzirom da je uniformnost malo praćena i analizirana postavili smo to za cilj u ovom radu. Uniformnost useva posebno postaje značajna osobina sa porastom i povećanjem značaja svetskog tržišta roba. Ona je redovno udružena sa smanjenjem diverziteta. Međutim, genetički diverzitet se može povećati gajenjem brojnih različitih homogenih sorata ili autohtonih populacija. Diverzitet useva se smatra poželjnim i bitnim u nekim klimatskim uslovima. Divergentne populacije koje su ranije zauzimale proizvodne kapacitete ublažavale su pad proizvodnje pod uticajem različitih stresnih uslova i na taj način smanjivale rizik. Gajenje uniformnih

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hibrida može rezultirati problemima u polinaciji kod kukuruza usled temperaturnog stresa koji je karakterističan u našem području. Diverzitet može biti povećan korišćenjem prirodnih populacija i gajenjem F_1 hibrida sa različitom dužinom vegetacije kod kukuruza.

Iz svega napred navedenog može se zaključiti da hibridi nisu najbolji za opstanak siromašnih farmera zbog značaja finansijskih ulaganja u seme i tehnologiju i opravdane zabrinutosti za nastali rizik usled gajenja neadaptiranih hibrida i smanjenja varijabilnosti kukuruza usled oplemenjivanja. Siromašni farmeri u ekstremnim uslovima održavaju genetički diverzitet kod različitih kultura i heterogenost sorata maksimalno adaptiranih datim uslovima u prostoru i vremenu. Preživljavanje u nepovoljnim godinama, ne prinos u povoljnim godinama je ključ opstanka siromašnih farmera. Ovo je verovatno važno za razvoj strategije u selekciji u cilju inkorporiranje gena za individualno ublažavanje posledica stresa inbred linija i hibrida. Za selekciju je bitno održavanje kontinuiranosti u potomstvu nosioca stabilnosti. Potomstvo može nastati selekcijom u povoljnim uslovima gde je genetička diferenciranost maksimalna, a uticaj spoljne sredine minimalan i oplemenjivanjem za različite uslove gajenja. Najverovatnije da je cilj selekcije stvaranje genotipova za date uslove spoljne sredine, što je u stvari približavanje napred navedena dva pristupa u selekciji. Ispitivanje i testiranje dobijenih genotipova mora imati ciljne uslove gajenja, lokacije.

Možda pri razvoju strategije treba imati na umu strategiju povećanja prinosa i opstanka farmera u ekstremnim uslovima, pri čemu ne dolazi do smanjenja prinosa kod najboljih genotipova, naročito adaptiranih samo na povoljne uslove koji bi se sastojali u poboljšanju uslova i kulture proizvodnje istovremeno. Potencijalna solusija za ove probleme mora biti ekonomska (najbolje moguće kreditiranje) i socijalna (edukacija), kao i tehničko-tehnološka (poboljšanje genotipova i tehnologije gajenja).

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