Synthetic Varieties: History, Development and Applications in Crop Improvement

Gebremedhin Welu
College of Agriculture & environmental science, Adigrat University, Tigray, Ethiopia, P.O.BOX=50
E-mail: gwtgere@gmail.com

Abstract
World population is increasing rapidly from time to time. Scientists expected to fulfill the demand of food by the highly increasing population of the era. So, one method of improvement to increase the yield is including synthetic varieties in the agriculture sector. Synthetics and the specialized populations derived from them-known synthetic varieties which are considered completely equivalent to synthetic cultivars are common products of plant breeding activities in a wide array of cross-pollinated species. A synthetic variety is developed through intercrossing of several genotypes of known superior combining ability. In order to use the synthetic varieties in breeding methods there should be clear information on their history, selection method, development, application, source and created population from them. So this paper is reviewed the history, development and applications of synthetic varieties in crop improvements.
Keywords: Combining ability, cross pollinated, population, synthetic varieties

1. Introduction

Synthetic varieties were first suggested by Hayes and Garber (1919) and defined by Lonnquist (1961) as open pollinated varieties (OPVs) derived from the intercrossing of selfed plants or lines known to possess high general combining ability (GCA), and subsequently maintained by routine mass selection procedures from isolated plantings.

Ultimately the commercial cultivars may be open-pollinated populations (synthetics or composites) and hybrids. The choice of cultivar depends upon resources, stage of breeding program, infrastructure and manpower for seed production and socioeconomic factors. Hybrid cultivars have the advantage of higher yield potential and uniformity. They are preferred over open-pollinated populations subject to higher level of heterosis. However, seed production of hybrids is costlier and a bit tedious and complicated (Dhillona and Prasanna, 2001).

Synthetics and the specialized populations derived from them-known as synthetic cultivars (also commonly referred to as synthetic varieties (Fehr, 1987) which are considered completely equivalent to synthetic cultivars here) are common products of plant breeding activities in a wide array of cross-pollinated species. Various definitions have been applied to these populations and some plant breeders have considered them to be equivalent, although this can lead to confusion. Following Lonnquist, (1961) a synthetic is an open-pollinated population maintained in isolated plantings that is derived from the random mating of selfed plants or lines or other genotypes (parents) produced from mass selection. As such, a synthetic is simply the bulked seed resulting from one or more cycles of population improvement that involve artificial selection.

Lonnquist (1949) defined a synthetic as an open – pollinated population formed by intercrossing of selfed plants or lines and subsequently maintained by mass selection. The term synthetic variety has come to be used to designate a variety that is maintained from open-pollinated seed following its synthesis by hybridization in all possible combinations among a number of selected genotypes which have been subjected to combining ability test. The components of a synthetic variety could be inbreds (usually) or mass selected populations in context of maize. The components are maintained so that the synthetic variety could be reconstituted as and when required (Mandal, 2014).

Synthetic varieties are open pollinated populations developed through random mating of selected genotypes (Lonnquist, 1961). Developing synthetic varieties through the use of full-sib and half-sib families or clones as parents is a commonly used breeding method in alfalfa (Flajoulot et al., 2005). Synthetic varieties have become increasingly favoured in alfalfa and other forage crops, mainly because it is cheaper than the development and use of hybrid varieties. Developing synthetic varieties also helps to minimize productivity loss with advancing generations of seed increase (Katepa-Mupondwa et al., 2002).

A synthetic variety is developed through intercrossing of several genotypes of known superior combining ability. Genotypes selected for synthetic variety development are those that are known to give superior hybrid performance when crossed in all combinations. Thus, properly selected male and female parents from diverse origin that can increase the possibility of heterosis when crossed are essential to successfully develop synthetic varieties. Therefore, before selecting clones for developing synthetic varieties, breeders should test the clonal progenies from polycross in yield trials, as indicated in (Busbice et al., 1974; Rowe and Gurgis, 1982).

In maize first inbreds are developed. The inbreds to be used as component lines are selected on the basis of combining ability for which component inbreds are crossed in all possible combinations. The inter-crossed seed is called as S_0 seed. Equal quantity of seed from all crosses is mixed and the mixture is allowed open-pollination in isolation and the seed is harvested. The harvested seed represents S1 generation. In absence of reconstitution of a synthetic variety at regular intervals, the synthetic variety becomes an open-pollinated variety (Mandal, 2014).

The overall performance of the synthetics depend mainly on the number of parental components, their general combining ability, their specific combining ability and on the total amount of heterosis (Seif and Link, 2007). Synthetics can be used by either farmers for commercial production or breeders as source populations from which to select new lines (Pandey et al, 1984). To utilize part of the heterosis in faba bean, synthetic cultivars were recommended for spring beans (Link et al., 1994) in Europe; the advantages of these cultivars are not only their partial use of heterosis, but also the possible increase in yield stability (Stelling et al., 1994).

There is no organized information on the synthetic population, their source, selection methods, developments and their application in agriculture. So this review is objected on providing of detailed materials on the above issues.

2. Synthetic Populations

This is a great way to create diverse new landraces and open-pollinated lines. Synthetic populations do better than regular open-pollinated types but are not as high yielding as F1 varieties (Rowen and Bryan, 2011). Improved varieties are synthetic cultivars, usually obtained through three or four generations of open pollinated reproduction of polycross seeds of selected parents (Flajulot *et al*., 2005).

Synthetic populations and the composite crosses described below are generally ways to generate diversity from which you can select, either by bulking or recurrent mass selection. Synthetics may also be bred as a goal in itself and the first initial crosses grown together in a mixture that is remade each year (or after several years). To create a synthetic population:

1. Start with two or more variable landraces or heirloom varieties.
2. Make all possible hybrid combinations between all plants. For example, if you started with Brandywine and Green Zebra tomatoes, you would make a hybrid using Brandywine as the mother and Green Zebra as the father (pollen source) and vice versa.
3. Pool all of the seeds of the hybrids together and plant them out.
4. Allow these plants to naturally and randomly homogenize and mix.
5. Over the next three to five generations, select out the best plants. (Rowen and Bryan, 2011)

In obtaining synthetic varieties in mixed species, the reasoning is broader than in allogamous varieties. In the latter, the general and specific combination capacity matter. In mixed species, maintenance of a synthetic variety involves crosses and natural self-pollination. The ideal is thus to select superior inbred lines derived from parents that also have good combination capacity. (Oliveira et al., 2012)

Synthetic variety breeding is most effective and intensive method to improve perennial forage crops like alfalfa through polycross. Classical breeding studies require long time to select individual clones for synthetic variety production (Moreno-Gonzales and Cubero 1994).

Synthetic varieties are populations that are generally created by intermating a set of proven inbred lines. Synthetics can achieve higher yield levels than older open-pollinated varieties that have received little systematic breeding for yield. They can also be propagated for many generations with little loss of yield. Several studies have shown that synthetics currently produce lower yields that are probably not acceptable to most farmers. The open-pollinated synthetic populations developed for breeding purposes generally produce lower yields, often one-third less than conventional hybrids. Some of these populations do have a high protein content in their grain (9-13%) relative to conventional hybrids (7-9%) so that protein and essential amino acid yields may be similar on a per acre basis. Such open-pollinated corn should have a higher feeding value and price as organic protein from other sources is expensive. (Hubbard et al., 2012)

A synthetic variety is developed by intercrossing a number of genotypes known for superior combining ability with high genetic distance. Therefore, synthetic variety is made up of genotypes previously tested for their ability to produce a superior progeny when crossed in all combinations in agreement with Ferreira et al. (1995) who emphasised that heterosis and the combining ability of parents depend directly on the genetic diversity between them and the chance of finding promising combinations is better when more divergent material is used.

Populations can be a result of crosses among a set of homozygous inbred lines (synthetic varieties), an open-pollinated variety, or a mixture of varieties and races (composites). General theories, however, make no distinction about the origin of the population unless it does not fill some of the basic requirements (Hallauer et al., 2010). Synthetic variety constitutes a poly morphical and stable population. Hence synthetic varieties are a high adaptation to environment variations. In other words synthetic varieties provide stable yield in the fluctuating environment (Phundan Singh, 2005).

Sowing seed of synthetic varieties is a common practice in forage species such as alfalfa (Medicago sativa L.) and orchargrass (Dactylis glomerata L.). Such varieties from selection and crossing of lines are phenotypically uniform but different genotypes. These lines to cross freely year after year to produce seeds, heterozygous and heterogeneous populations originate. The use of artificial seed allows multiplication of outstanding genotypes and genetically uniform, since this method does not require that annually cross-pollination is carried out to produce plants (McKersie and Brown, 1996).

3. History of Synthetic Varieties

Although nine decades of years elapsed on discovery of heterosis of hybrid maize, but the synthetic varieties of this crop still cover the greatest part of planted area in developed countries other than, Farmers can also used synthetic maize seed without buying seeds every season. It has been suggested that synthetic maize varieties would be of considerable value, where the cost of hybrid seeds is high relative to the value of the expected crop (Mohammed, 2013). Synthetic varieties were first suggested by Hayes and Garber (1919).

It seems that the history of creating synthetic populations out of local populations, the fact that they were not initially involved in an initial inbreeding process and that crossings and selection started with heterozygous forms kept the recessive genes in the population, with adverse effects, one of which being the lower value of the general combining ability. (Muntean et al., 2014)

4. Sources of Synthetic Populations

Development of synthetic varieties requires the development of inbred lines, their testing for general combining ability, making their all possible cross combinations, predicting the F2 performance constituting a number of experimental synthetics, testing their yield levels in yield trials over locations, and finally releasing those which excel the standard checks. In India, one of the experimental synthetic populations ‘‘Syn 65’’ has been released for cultivation in the name of cv. ‘‘Sangam.’’ In lotni brown sarson (B. campestris), Pusa Kalyani has been developed and released as cultivar from the IARI research station Kanpur (UP) utilizing this breeding approach (RAI et al., 2007).

Examining the relationships among progeny tests (correlations, heritability, components of additive and genetic variances) is of great importance in determining which of the tests is the most suitable (effective) for the purposes of breeding and developing synthetic varieties (Milic et al., 2010).

Maize (*Zea mays* L.) synthetic populations are low-cost and stable varieties, obtained by cross pollination of a group of inbred lines. They are a viable alternative for situations where the use of hybrid seed and related inputs are too expensive. Although synthetic populations are generally less productive than heterotic hybrids, their main advantage is that the heterosis does not diminish significantly in F2 (Bernardo, 2002). Besides the inbred lines, maize synthetics can be obtained from hybrids or local populations. Obtaining maize synthetics from local populations aims at enriching the gene pool with a large number of valuable genes derived from local population characteristic to some agricultural areas (Coe et al., 1988).

These positive aspects come to support the approach promoted by CIMMYT (1999) in order to obtain highly productive synthetic populations of maize, which is of great importance mainly in places where the use of hybrid seed is too expensive (especially in developing countries). From that year on, synthetic maize populations have acquired a special importance as objectives of research in the field.

Breeders want to improve synthetic populations of maize for using them in obtaining superior inbred lines necessary for hybridization programmers. The value of any maize population depends on its potential per se and on its combining ability in crossings (Lamkey and Edwards, 1999). The per se value of synthetic populations of maize has been studied for many traits: productivity, earliness, resistance to falling (Gulea, 2011; Has, 2000), resistance to *Sesamia nonagrioides* Lef. and *Ostrinia nubilalis* (Velasco et al., 1999).

Knowledge about genetic variability in species is important for optimal use of genetic resources in plant breeding programs. The use of molecular markers especially AFLP (Amplified fragment length polymorphism) markers help to select genetic dissimilarity potential parents for production of synthetics (Kidwell et al., 1994).

5. Development of Synthetic Varieties

A synthetic variety is a variety produced by crossing in all combinations a number of inbred lines (with high GCA that combine well with each other) and a synthetic variety is maintained by open pollination in isolation. In maize, development of synthetics includes:

- Evaluation of lines on the basis of general combining ability.
- These selected lines are intercrossed in all possible combinations.
- Equal amount of seed from these crosses is composited to constitute a synthetic (Singh and Kota, 2007).

The first objective in the development of synthetic varieties is to increase the gene frequency for specific attributes (Hallauer and Eberhart, (1966). The basic concept in the development of synthetic varieties is exploitation of heterosis or hybrid vigor, such as varieties are constituted from general combining ability inbreds. However, heterosis is partially utilized by synthetic varieties because some level of inbreeding takes place to open pollination in later generations. Synthetic exploit more of additive gene action whereas hybrid exploit more non additive (over dominance and epistatic) gene action (Mohammed, 2013).

A synthetic variety is developed by intercrossing a number of genotypes known for superior combining ability with high genetic distance. Therefore, synthetic variety is made up of genotypes previously tested for their ability to produce a superior progeny when crossed in all combinations (Gülbitti-onarici et al., 2009)

6. Selection Methods for Synthetic Variety

Mass selection and phenotypic selection are the selection methods for synthetic variety development. Molecular markers have been widely used for genetic diversity studies and marker assisted selection for synthetic variety development (Maureira and Osborn, 2005).

Selecting inbred lines based on their GCA in defined crosses is used to develop synthetics and improve yield when selection is directly on yield (a trait of very low heritability) has a limited effect. This suggests that while the inheritance of combining ability is a quantitative trait governed by many genes, each has a larger individual effect than would genes that contribute directly to yield. Lines with high GCA presumably have a larger proportion of favorable yield genes which differ from other lines measured with respect to their specific favorable gene complex (Lonnquist, 1951).

Measurements of GCA can be obtained from multiple top crosses made between a line and various elite inbreds, and these crosses are phenotyped for yield in multiple locations and years. Although specific combining ability (SCA) is more important from the standpoint of obtaining maximum yields in hybrid crosses, GCA is highly important in developing high yielding synthetics. Line performance in top crosses has been shown to be relatively constant after the S1 generation (Jenkins, 1935; Sprague, 1946) and consequently little or nothing would be gained by additional selfing where the production of synthetic varieties is the goal (Lonnquist, 1949).

Open pollinated varieties developed by modern plant breeding were historically used as commercial cultivars by farmers, and replaced the older landraces that had been selected directly by the farmers. Later, the best OPVs were selected as source populations for further plant improvement and development of synthetics and modern hybrids. In the 1920s, nearly one thousand cultivars available in the United States Corn Belt were selfed in an attempt to develop useful inbred lines (Troyer, 1999). These were often intercrossed to create synthetics. One of the most popular, Iowa Stiff Stalk Synthetic (BSSS), was developed by GF Sprague in the early 1930's by intermating 16 inbreds (Hallauer and Miranda, 1988), and is considered an excellent source population for the selection of inbred lines with high combining ability with other elite inbred lines.

THAD (1966) reported that the rate of change in inbreeding in synthetic varieties per generation, is always greater than 1/2, for diploid, equilibrium is reached in one step past SYN 1, i. e., in the SYN 2, involved from 2 to 64 parents. In order to evaluate a synthetic variety we need to predict the yield performance of SYN 2. Practicing prior recurrent selection in the population should increase the occurrence of more homozygous mother plants with good performance in crosses and negligible inbreeding depression. This should be possible from the wide genetic variation detected. Such a fact will favor obtaining superior synthetic varieties (Oliveira et al., 2012). The amount of seeds of a synthetic cultivar is multiplied by successive generations of random mating without selection; these generations are called Syn-2, Syn-3, and so on (Busbice, 1969).

7. Applications of Synthetic Varieties

The prime synthetics have confirmed to be a precious resource of genetic variability for disease resistance. Synthetic wheat also showed resistance to leaf blotch, glume blotch, crown rot, yellow leaf spot, leaf blight, powdery mildew, karnal bunt (Van Ginkel and Ogbonnaya, 2007).

Breeding through synthetic variety is most effective and intensive method to improve perennial forage crops like alfalfa through polycross. Classical breeding studies require long time to select individual clones for synthetic variety production (Moreno-Gonzales and Cubero 1994). The use of molecular markers especially AFLP (Amplified fragment length polymorphism) markers help to select genetic dissimilarity potential parents for production of synthetics (Kidwell et al. 1994).

The vast majority of fruit species are propagated by vegetative means because of the presence of self-incompatibility and breeding cycles very long. The use of synthetic seed facilitates its spread. However, the most useful artificial seed would be in the conservation of germplasm of these species (Towill, 1988)

8. Synthetic Genomics

Synthetic genomics has been defined as "the engineering of biological components and systems that do not exist in nature and the re-engineering of existing biological elements; it is determined on the intentional design of artificial biological systems, rather than on the understanding of natural biology" (Synbiology, 2006). Synthetic biology aims to design and model novel biomolecular components, networks and pathways. These are then applied to rewire and reprogram organisms to provide solutions for various challenges (Khalil and Collins, 2010). One of the goals of synthetic genomics is the preparation of viable minimal genomes which will function as platforms for the biochemical production of chemicals with economic relevance. The production of biofuels, pharmaceuticals and the bioremediation of environmental pollution are expected to constitute the first commercial applications of this new technique. Synthetic biology has enabled the construction of a gene that encodes the same amino acid sequence as the plant enzyme but that is optimized for expression in the engineered microorganism of choice. This method has provided massively parallel throughput which has made it possible to identify and track genetic variation among the various strains, providing insights into why some strains are better than others (BIO, 2013).

9. Conclusion

The challenge of scientist in this century is fulfilling the demand of the population with rapid increment. Synthetic varieties may take the vital role for doing so. As different varieties use this method of improvement for diseases resistance, as a method of multiplication and for conserving in germplasm for a long period of time it will be a suited choice of breeding for the future.

Reference

Bernardo, R. (2002), *Breeding for Quantitative Traits in Plants*. Stemma Press, Woodbury, MN.

Biotechnology Industry Organization (BIO) (2013), Current Uses of Synthetic Biology for Renewable Chemicals, Pharmaceuticals, and Biofuels. 1201 Maryland Ave. SW, Suite 900, Washington, DC 20024

Busbice, T.H., O.J. Hunt, J.H. Elgin, & R.N. Peaden (1974), Evaluation of effectiveness of polycross-progeny and self-progeny tests in increasing yield of alfalfa synthetic varieties. *Crop Science* 14, 8-11.

Busbice, T. H. (1969), Inbreeding in synthetic varieties. Crop Sci. 9: 601-604.

CIMMYT, (1999), *Development, Maintenance, and Seed Multiplication of Open-Pollinated Maize Varieties.* 2nd ed., CIMMYT, Mexico, D.F.

Coe, E. H., M. G. Neuffer and D. A. Hoisington (1988), *The Genetics of Corn*. In: G.F. Sprague and J.W. Dudley, editors, Corn and Corn Improvement, Third edition: 81-258. ISBN 0-89118-099-0.

Dhillon, B. S., B. M. Prasanna (2001) Maize in V. L. Chopra (ed.). Breeding Field Crops: Theory and Practice. Oxford and IBH, New Delhi.

Fehr, W.R. (1987), Principles of Cultivar Development,. Theory and Technique; Macmillan Publishing: New York; Vol. 1, 1–536.

Flajoulot, S., J. Ronfort, P. Baudouin, P. Barre, T. Huguet, C. Huyghe & B. Julier (2005), Genetic diversity among alfalfa (*Medicago sativa*) cultivars coming from a breeding program, using SSR markers. *Theoretical Applied Genetics* 111, 1420-1429.

Ferreira, D.F., A.C. Oliveira, M.X. Dos Santos, and M.A.P. Ramalho (1995), Métodos de avaliação da divergência genética em milho e suas relações com os cruzamentos dialélicos. Pesquisa Agropecuária Brasileira 30: 1189-1194.

Gulbitti-onarici S., H. Kendir, C. sancak, C. S. Sevimay, H. Ekiz, S. Ozcan (2009), Genetic Relationships Among *Medicago sativa* L. Clones Commonly Grown in Central Anatolia. Tarim bilimleri dergisi, 15(2) 142-147

Hallauer, A. R. and S. A. Eberhart (1966), Evaluation of synthetic varieties of maize for yield. Crop. Sci., 6, 423 – 427.

Hallauer, A.R., J.B.F. Miranda (1988), Quantitative genetics of maize. Iowa State Univ Press, Ames

Hallauer, A.R., M.J. Carena, J.B Miranda Filho, (2010), *Quantitative Genetics in Maize Breeding*. Springer. ISBN: 978-1-4419-0765-3. XVl, 664 p.

Has, V. (2000), *Cercetări privind determinismul genetic al unor caractere calitative şi cantitative la porumbul zaharat* (In Romanian, Ph.D. Thesis). Academia de Stiinte Agricole si Silvice „Gheorghe Ionescu-Sisesti", Bucureşti.

Hayes, H.K., R.J. Garber (1919), Synthetic production of high protein corn in relation to breeding. J Am Soc Agron 11: 309-318.

Hubbard, K., M. Colley, and J. Zystro (2012), Organic Seed Growers Conference Proceedings. January 19-21, 2012, Port Townsend, WA. Organic Seed Alliance, Port Townsend, WA. 151 pp.

Jenkins, M.T. (1935), The effect of inbreeding and selection within inbred lines of maize upon the hybrids made after successive generations of selfing. Iowa State College J of Sci 9: 429-450.

Khalil, A. S. and J. J. Collins (2010), Synthetic biology: applications come of age. *Nature reviews. Genetics*, 11:367{379, 2010. ISSN 1471-0056. doi: 10.1038/nrg2775.

Katepa-Mupondwa, F.M., B.R. Christie, & T.E. Michaels (2002), An improved breeding strategy for autotetraploid alfalfa (*Medicago sativa* L.). *Euphytica* 123, 139-146.

Kidwell, K.K., E.T. Bingham, D.R. Woodfield and T.C. Osborn (1994), Relationships among genetic distance, forage yield and heterozygosity in isogenic diploid and tetraploid alfalfa populations. Theoretical and Applied Genetics 89: 323-328.

Lamkey, K. R., and J. W. Edwards (1999), *The Quantitative Genetics of Heterosis*. In: Coors, J.G. and Pandey, S. (editors), Proceedings of the International Symposium on the Genetics and Exploitation of Heterosis in Crops, CIMMYT, Mexico City, Mexico, 17-22 August 1997. ASA, CSSA, and SSSA, Madison, WI: 31-48;

Link W., Ederer W., von Kittlitz E., Zuchtmethodische Entwicklungen Nutzung von, (1994) Heterosis bei Fababohnen. Vortr. Pflanzenzüchtg. 30 201-230.

Lonnquist, J.H., (1949), The development and performance of synthetic varieties of corn. Agron J 41: 153-156

Lonnquist, J.H. (1951), Recurrent selection as a means of modifying combining ability in corn. Agron J 43: 311-315.

Lonnquist, J.H. (1961), Progress from recurrent selection procedures for the improvement of corn populations. *Nebraska Agricultural Experimental Station Research Bulletin* 197, 1-34.

Mohammed A. H. (2013), Breeding to Derive a New Suitable Maize (*Zea mays* L.) Variety for Spring Season. Journal Tikrit Univ. For Agri. Sci. Vol. (13) No. (3)

Mandal, B. C. (2014), Maize Breeding and Seed Production Manual Food and Agriculture Organization of the United Nations Office of the Food and Agriculture Organization in DPR Korea.

McKersie, B.D. and D.C.W. Brown (1996), Somatic embryogenesis and artificial seeds in forage legumes, *Seed Sci. Res.,* 6, 109-126.

Maureira, I. J. & T.C. Osborn (2005), Molecular markers in genetics and breeding: Improvement of alfalfa (*Medicago sativa* L.). In: Lorz, H., & Wenzel G (eds.) Biotechnology in Agriculture and Forestry. Vol ume 55, pp. 139-154.

Milic, D., S. Katic, J. Bocanski, D. Karagic, A. Mikic and S. Vasiljevic (2010), Importance Of Progeny Testing In Alfalfa Breeding (*Medicago Sativa* L.). GENETIKA, Vol. 42, No. 3, 485-492.

Moreno-Gonzales, J. and J.I. Cubero (1994), Selection strategies and choise of breeding methods. In: Plant Breeding. (Eds. Hayward, M.D., Bosemark, N.O. and Omagosa, I.), Chapman and Hall, London, UK.

Muntean, L., I. Has, V. Has, A. Gulea, S. Muntean (2014), Combining Ability for Yield in Maize Synthetic Populations Obtained From Local Populations. Romanian Agricultural Research, No. 31, 1222-4227.

Oliveira, I.J., M. D. Zanotto, M. Krieger and R. Vencovsky, (2012), Inbreeding depression in castor bean (*Ricinus communis* L.) progenies. Crop Breeding and Applied Biotechnology 12: 269-276.

Pandey, S., V. SK, L. C. De, A. Ortega, G. Granados, E. Villegas (1984), Development and improvement of maize populations. Genetika 16: 23-42.

Phundan Singh, (2005), Essential of Plant Breeding publisher, New Delhi. P.160 – 162.

Rowen W. and Bryan (2011), A Step-By-Step Guide for Growers of Organic Vegetables. Connolly Edited By Elizabeth Dyck. Northeast Organic Farming Association of New York, Inc. (NOFA-NY)

Seif, G., W. Link (2007), Agronomic Performance and the Effect of Self-Fertilization on German Winter Faba Beans. Journal Of Central European Agriculture,Volume 8: No. 1 (121-128).

Singh, S.S., and S. Kota (2007), Breeding of Field Crops (Cereals). Indian Agricultural Research Institute, New Delhi-110012

Sprague, G.F. (1946), The experimental basis for hybrid maize. Biological Reviews 21: 101-120.

Stelling, D., W. Link, E. Ebmeyer (1994), Yield stability in faba bean, Vicia faba L. 2. Effects of heterozygosity and heterogeneity. Plant Breeding 112: 30-39.

Towill L.E., (1988). Genetic Considerations for clonal germplasm preservation of materials, *HortScience,* 23, 91-93.

Troyer, A.F. (1999), Background of U.S. Hybrid Corn. Crop Sci 39: 601-626.

Van, G. M. and F. Ogbonnaya (2007), Novel genetic diversity from synthetic wheats in breeding cultivars for changing production conditions. Field Crop Res. 104:86-94.

Velasco, P., R.A. Malvar, P. Revilla, A. Butron and A. Ordas, (1999), *Ear Resistance of Sweet Corn Populations to Sesamia nonagrioides (Lepidoptera: Noctuidae) and Ostrinia nubilalis (Lepidoptera: Pyralidae)*. Journal of Economic Entomology, 92(3): 732-739.

The IISTE is a pioneer in the Open-Access hosting service and academic event management. The aim of the firm is Accelerating Global Knowledge Sharing.

More information about the firm can be found on the homepage:
http://www.iiste.org

CALL FOR JOURNAL PAPERS

There are more than 30 peer-reviewed academic journals hosted under the hosting platform.

Prospective authors of journals can find the submission instruction on the following page: http://www.iiste.org/journals/ All the journals articles are available online to the readers all over the world without financial, legal, or technical barriers other than those inseparable from gaining access to the internet itself. Paper version of the journals is also available upon request of readers and authors.

MORE RESOURCES

Book publication information: http://www.iiste.org/book/

Academic conference: http://www.iiste.org/conference/upcoming-conferences-call-for-paper/

IISTE Knowledge Sharing Partners

EBSCO, Index Copernicus, Ulrich's Periodicals Directory, JournalTOCS, PKP Open Archives Harvester, Bielefeld Academic Search Engine, Elektronische Zeitschriftenbibliothek EZB, Open J-Gate, OCLC WorldCat, Universe Digtial Library , NewJour, Google Scholar