Advance Journal of Food Science and Technology 10(10): 780-786, 2016
DOI: 10.19026/ajfst.10.2261
ISSN: 2042-4868; e-ISSN: 2042-4876

Submitted: July 2, 2015 Accepted: August 11, 2015 Published: April 05, 2016

Research Article

Theories and Technical Systems for Crop Grey Breeding Science and Their Applications

Guo Ruilin, Lu Zhifang, Liu Yafei, Zhang Shulin and Wu Qiufang
School of Biological and Food Engineering, Anyang Institute of Technology, Anyang 455000, P.R. China

Abstract: This study discussed the discipline structure of crop grey breeding science and its features and summarized the theories and technical systems for crop grey breeding science which are consisted of five systems, eight theories, nine principles, a technical route and a computer decision-making system. Under the guidance of the theories and methods, breeding workers have bred 27 new varieties, such as 4 wheat varieties, 3 mung bean varieties, 6 cotton varieties, 4 millet varieties, 1 soybean variety, 1 cowpea variety, 1 pumpkin variety, 1 sweet corn variety, 2 mulberry varieties, 1 silkworm variety, 3 reygrass varieties and so on. The popularization and application of these varieties in production has huge economic and social benefits, thus provides a strong support for the feasibility of theories and technical systems of crop grey breeding science from the perspective of breeding practice.

Keywords: Application, crop, crop grey breeding science, technical system, theory

INTRODUCTION

Crop grey breeding science is a emerging interdisciplinary subject combined grey system theory (Deng, 1982; Liu *et al*., 2010) with crop breeding theory, which was advanced in the late 1980s. Since the book Crop Grey Breeding Science (Guo, 1995) came out in 1995, after more than 10 years of development, the crop grey breeding science has made great progress from theory to practice. Up to now, the academic framework of crop grey breeding science has been basically formed and has laid a certain academic status in academia, distinguishing features of which are five systems, eight theories, nine principles, a technical route and a computer decision-making system (Guo and Guan, 2005; Guo and Wang, 2008). Its proposition and application has great significance for the breeding worker understanding and mastering the crop breeding laws, controlling the breeding process, improving the efficiency of breeding, across from the traditional experience breeding to the quantification breeding and promoting the development of plant breeding. The purpose of this study is to conclude and summarize the theories and technical systems of crop grey breeding science and their applications, so that provides a new effective tool or means for breeding workers breeding new crop varieties.

SUBJECT COMPOSITION OF CROP GREY BREEDING SCIENCE AND ITS FEATURES

Subject composition of crop grey breeding science: Crop grey breeding science is rooted in crop breeding science. Complexity of plant breeding system determines that the crop grey breeding science is an integrated subject with multi-disciplines. It is this integration that makes the subject more vigour and anima. Crop grey breeding science can be divided into two parts: basis of crop grey breeding science and methodology for crop grey breeding science (Fig. 1). It is in the basis part that reflects the integrated effect.

Without saying, as a foundation subject, crop breeding science and grey system theory become important members of the crop grey breeding science. Due to their origin relationship with crop breeding, other disciplines should also be selected (Fig. 1). It is well known that the first thing to do is setting breeding targets in crop breeding process, its theory basis can't do without ecology knowledge; Breeding materials in plots to thrive and robust development need the theory of soil fertilizer and cultivation for support; Hybrid combination to achieve gene recombination, making various genetic features to be full performance, the knowledge of genetics and quantitative genetics are essential; Breeding for plant type and high photosynthetic efficiency to research plant form and physiological characteristics, the principles of plant physiology are indispensible; Breeding for resistance to insects and diseases requires solid basic knowledge of plant pathology and entomology; Transgenic breeding to understand the genes of target characters and their functions has need of knowledge for modern molecular biology and biotechnology; Field engineering and test in breeding process to achieve scientific and reasonable, the knowledge of experimental design and statistical analysis can gave a good account of themselves; To fully utilize and faster processing breeding experiment

Corresponding Author: Guo Ruilin, School of Biological and Food Engineering, Anyang Institute of Technology, Anyang 455000, P.R. China

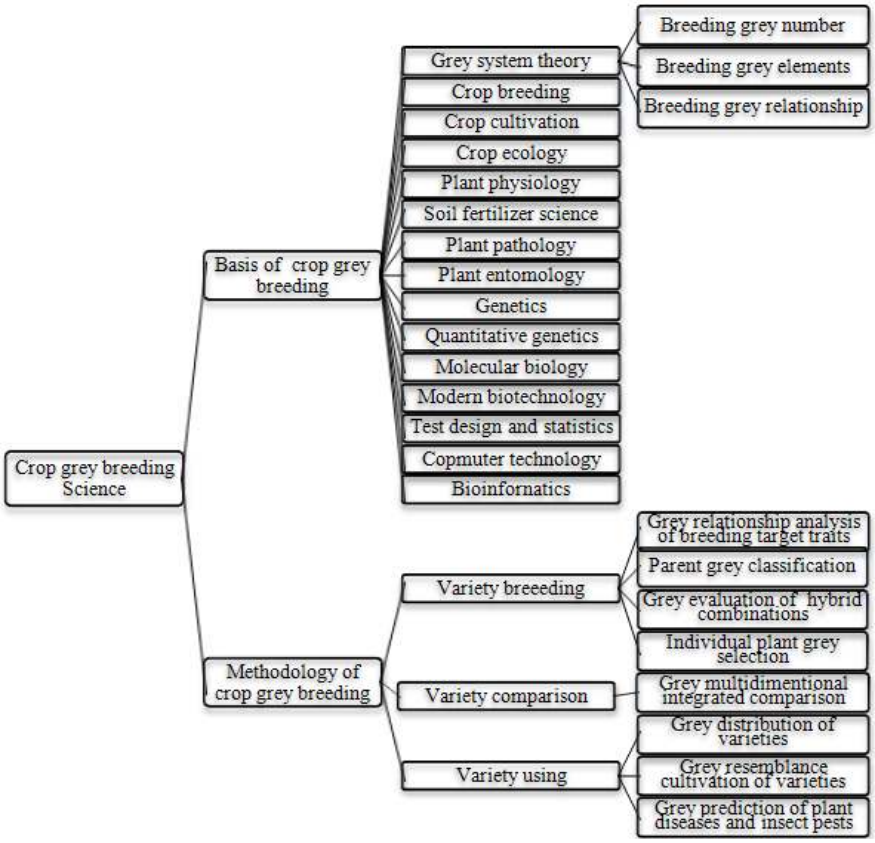

Fig. 1: Subject composition of crop grey breeding science

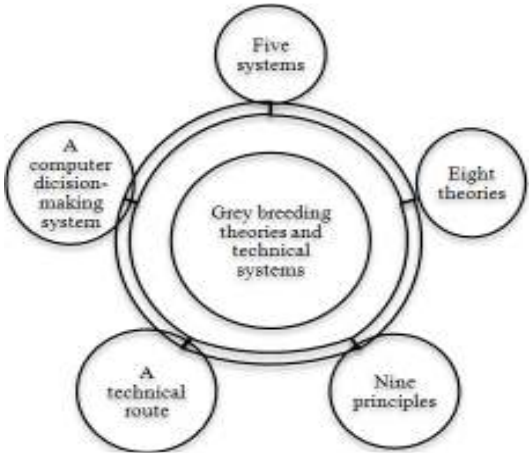

Fig. 2: Grey breeding theories and technical systems

data, the knowledge of bioinformatics and computer principle comes in.

This shows that the crop grey breeding science combines many disciplines into one subject, thus giving it the obvious "hybrid superiority", forming some new different features from traditional experience breeding.

Features of crop grey breeding science: Compared with the traditional experience breeding, crop grey breeding science reveals the following four characteristics: First is to elucidate the phenomena of crop breeding process, not only giving qualitative explanation, also giving the quantitative description. The crop grey breeding science can not only learn from the wisdoms and experiences of many breeding workers for years, but also make them more theoretical, systematic, standardized and programmed, thus impelling the subject of crop breeding to develop into a precision science. Second is to consider comprehensively multiple factors and describe the complex causal relationships in crop breeding process. For a number of factors that affect breeding target characters, which is the main, which is a minor, it can give a clear answer. Third is to take full advantage of breeding information to explain the phenomenon of breeding and make optimal decisions for the key stages or links of the breeding process, the results of which can guide breeding new crop varieties and significantly improve the selection efficiency and effects. Fourth is to introduce principles of computer and technology and build programs that are norm and convenient operation, even if you are green hands of breeding, you can also reach the decision-making level of breeding expert. This shows that the theory and methods of crop grey breeding may be very practical tools and instruments at the hands of the breeding workers. Compared with the

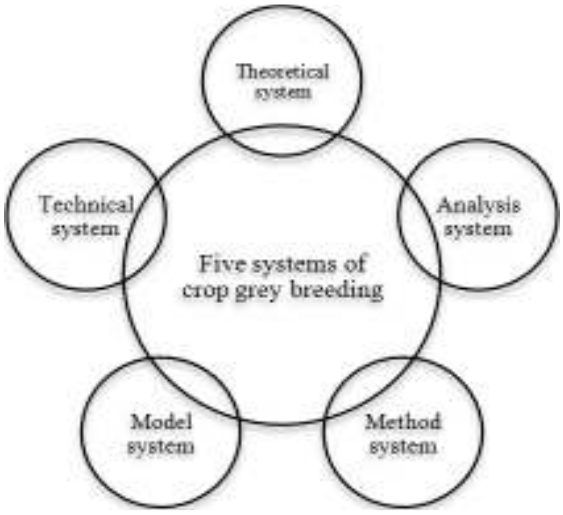

Fig. 3: Five systems of crop grey breeding

traditional experience breeding, it is a theoretical leap and breakthrough.

Theories and technical systems of crop grey breeding science: The kernel and essence of crop grey breeding science is its theories and technical systems which are consisted of five systems, eight theories, nine principles, a technical route and a computer decision-making system (Fig. 2).

Five systems: Including the theory system taken the crop breeding theory and grey hazy set as its basic skeleton and the kernel, the analysis system relied on grey relational space, the method system based on the grey sequence generation, the model system taken the GM grey model as its core and the technological systems taken the grey classification, grey assessment, grey layout, grey prediction and grey relationship analysis for crop breeding as its subject (Fig. 3).

Theory system: Crop grey breeding science takes the crop breeding theory and grey hazy set as its basic theory pillars, coupling with other theories. These theories are complementary each other. The significant difference between the theory system and the traditional crop breeding is that it describes crop breeding object in form of information covering facing with the crop breeding system that information is not full and reveals and expresses crop breeding phenomenon with grey number, grey element, grey relationship, grey matrix and grey equation, thus it is more objective and science, which has laid the solid foundation for achieving informationization, quantification and scientification of crop breeding.

Analysis system: The essence of analysis is comparison. Crop breeding is essentially comparison of breeding objects that is an overall comparison based on grey relational space, combined point set topological space with metric space and had a reference system and a measure. This analysis system can make analysis of overall situation and panorama by quantifying and sequencing of plant breeding system factors with incomplete information, so as to distinguish the main and secondary factors affecting the breeding system.

Method system: Crop grey breeding methodology is based on the grey sequence generation. So-called grey sequence generation is through some kind of operation transforming the original breeding data into the new data. Usually there are three kinds of transformation methods. The first method is hierarchical transformation which may change the level of breeding data by generating operation, such as accumulating generation and inverse accumulating generation method, etc.. The second method is data transformation which may transform the incomparable breeding data into the comparable breeding data by generating operation, such as initial value generation, mean value generation and interval value generation, etc. The third method may transform the breeding data or sequence with different polarity into the ones with same polarity by generating operation, such as upper effect measure, moderate effect measure and lower effect measure method, etc.. Through these transformation methods, the relationships among different dimensional characters of breeding objects are able to manifest, the breeding rule hidden in the breeding data is able to reveal.

Model system: The core of a model system for crop grey breeding is GM grey model. This model is neither a general functional model, nor a pure difference equation model, or pure differential equation model, but rather a model with partial difference, partial differential properties, which is uncertain whether in the relationship, or in the nature and or in the connotation. Breeding sequence is usually limited sequence. Differential equation model established in this sequence is essentially an infinite difference information model set up by using the finite difference information model, this is also the difficulty of crop grey breeding modeling. So the modeling idea is to analyze general differential equation from the perspective of breeding sequence, so as to understand its main composition conditions, then, to establish approximate differential equation models (incomplete information) to the breeding sequence of meeting these conditions approximately. This model based on the fact that is “less data, poor information”, achieved the change from traditional models of studying the history rule to studying the reality rule, is an effective complement to the traditional model.

Technical system: Technical system of crop grey breeding is taken the grey classification, grey

evaluation, grey layout, grey prediction and grey relationship analysis as the main body. Among them, the grey classification including grey relational fuzzy classification, the grey relational Q type system classification, the grey relation R type system classification, the classification of grey relational graph and the maximal tree grey similarity relation classification, etc.; grey evaluation including grey evaluation of hybrid combination, variable weight selection of grey selected character for individual plant, fixed weight selection of grey character for individual plant, equal weight selection of grey character for single plant, variety multidimensional comprehensive membership evaluation, variety multi-dimensional grey correlation degree comprehensive evaluation, grey effect function multi-dimensional comprehensive evaluation, variety multi-dimensional grey fuzzy comprehensive evaluation, variety multi-dimensional grey statistic comprehensive evaluation and grey resemblance cultivation, etc.; grey layout including variety grey single target layout, variety center grey target layout, variety grey relational layout and variety grey clustering layout, etc.; grey prediction including the grey disaster prediction of plant diseases and insect pests and season grey disaster prediction of plant diseases and insect pests, etc.; grey relationship analysis including grey correlation analysis, generalized grey correlation analysis, grey point relational analysis and grey advantage analysis, etc. The technology system covers the whole process of crop breeding, can effectively guide the breeding of new varieties.

Eight theories: Including grey relational analysis theory of breeding target characters, parent grey clustering theory, grey evaluation theory of hybrid combinations, individual plant grey selection theory, multidimensional comprehensive comparison theory of varieties, grey layout theory of varieties, grey resemblance cultivation theory of varieties and grey prediction theory of plant diseases and insect pests, etc.. These theories have detailed descriptions in the literature (Guo, 1995; Guo and Guan, 2005), not repeat them here (Fig. 4).

Nine principles: Including the breeding default principle, breeding implied denial principle, breeding difference information principle, breeding information cognitive principle, breeding whitening principle, non-uniqueness principle of the breeding solution, priority principle of new breeding information, breeding minimum information principle, breeding grey eternal principle, etc. For their details, please refer to the literature (Guo and Wang, 2008).

A technical route: Based on five systems, eight theories and nine principles above-mentioned, combined with the breeding practice, we have established crop grey breeding technology route, that is: using breeding grey relationship analysis theory, to determine objective and reasonable breeding targets; using parent grey classification theory for Science classification to parents, to make up hybrid combinations; using hybrized combination grey evaluation theory for assessment to hybrid combinations in F_1, to determine key combinations and planting scale of F_2; using single plant grey selection theory, to ascertain the grade of single plants selected in field and make one's choice; using variety grey multidimensional integrated comparison theory, to appraise varieties or strains selected in field comprehensively and screen good strains or varieties; using variety grey layout theory, to confirm suitable ecological planting district of varieties; using variety grey resemblance cultivation theory, to achieve combining the elite cultivar with good cultural technique; using grey forecast theory of pests and diseases, to forecast occurring and popular trend of pests and diseases, put forward warning countermeasures and full play potential of yield and quality of varieties. This technique route, establishing its own system, having unique style, has now become more and more maturity as a new and an effective breeding approach and has gradually accepted by the breeding workers, whose importance has been or is being reflected in the practice of breeding.

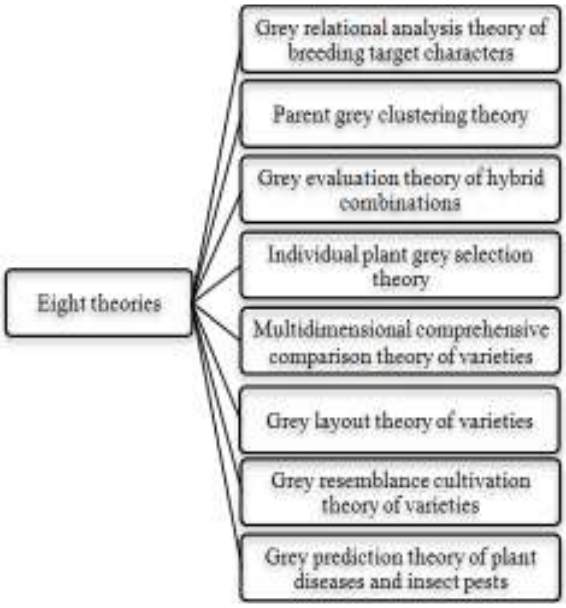

Fig. 4: Eight theories of crop grey breeding

A computer decision-making system: That is a computer decision-making system for crop grey breeding, which has been developed based on the book "Crop Grey Breeding Science", making theories and methods above-mentioned running through various stages or links in crop breeding be compiled into a

computer program. Advent of the system provides a fast and effective decision-making platform for the breeding worker, making the breeding workers be freed from the cumbersome and complex data processing services, which contributed significantly to the promotion and application of theories and methods of crop grey breeding, has had a good effect in the breeding process. On this basis, the academic monograph "Computer Decision System for Crop Grey Breeding and Its Application" was published by the Chinese Agricultural Science and Technology Press (Guo and Wang, 2008) and was classified as a State "Eleven-Five" Key Book, producing a significant impact in the national genetic breeding. In 2011, the book won first prize in the first natural science outstanding academic works in Henan province.

APPLICATIONS OF THEORIES AND TECHNICAL SYSTEMS OF CROP GREY BREEDING SCIENCE IN CROP BREEDING

Crop grey breeding science is emerged in the process of combination of theory research and application research of crop breeding, so its theories and technical systems have had a very strong applicability and practicality since the beginning of the advent of them, has been applied in many ways and has achieved obvious results. According to China Hownet (CNKI) Academic Literature Retrieval, so far, more than 2000 researchers in more than 400 breeding units throughout the country are using the grey breeding theory to develop crop breeding research and have published more than 500 research papers (including 36 master's papers, 8 doctoral dissertations). Its application range covers 107 kinds of plants and animals in 19 classes such as rice, wheat, corn, cotton and so on (Table 1).

The research contents include breeding key links or phases such as the relationship analysis of breeding target characters, parents classification, evaluation of hybrid combinations, single-plant selection, comparison of varieties (or lines), layout of varieties and similar cultivation of varieties and so on (references to omit). Under the guidance of the theory and methods, 27 new varieties such as wheat, mung bean, cotton, millet, beans, peas, pumpkin, sweet corn, mulberry, the high quality silkworm and so on have been cultivated (Guo *et al*., 1996, 1999a, b, 2002, 2006; Xue *et al*., 1994; Guo, 2007; Wang *et al*., 2003, 2005; He *et al*., 2004; Li and Chen, 2003; Chen *et al*., 1999; Yan *et al*., 2001; Luo, 2009; Huang and Lu, 2001; Hao *et al*., 2005) and 1 national scientific and technological progress second prize, 2 provincial scientific and technological progress first prize, 1 provincial scientific and technological progress second prize, 1 city-level scientific and technological progress first prize, 5 city-level scientific and technological progress second prize have being gained, creating a huge social and economic benefits (Guo *et al*., 2014). These provide some powerful evidences from the perspective of breeding practice for the feasibility of the theories and technical systems of crop grey breeding science.

The development prospect and outlook of crop grey breeding science: To sum up, theories and technical systems of crop grey breeding science overcome the limitations of the traditional experience breeding, improve the breeding efficiency of the new crop varieties, have realized the quantification, informatization and scientification in plant breeding and

Table 1: Application fields and ranges of crop grey breeding theory

Species	Name
Foods	Wheat, corn, rice, millet, barley, sorghum, mung bean, cowpea, kidney bean, broad bean, hulless barley, broom corn millet, triticale, buckwheat, oat
Oils	Soybean, peanut, rape, sunflower, castor, Oil camellia
Fibers	Cotton, linen, ramie, kenaf, jute
Potato	Sweet potato, potato, konjaku, Chinese yam
Smoke sugar	Tobacco, sugar beet, sugar cane, cut hand honey
Fungus	Mushroom, coprinus comatus, oyster mushroom
Melons	Cucumber, watermelon, melon, bitter melon, squash， pumpkin
Fruit class	Jujube, cashew nuts, pistachio, chestnut, pear, loquat, plums, mango, peache, cantaloupe, papaya， grape
Vegetables	Chinese cabbage, radish, tomato, chili, pickle, pea bean, cabbage
Medicinal class	Basil, erigeron breviscapus, safflower, artemisia annua, pepper
Flowers type	Roses, Chinese flowering crabapple, crape myrtle, pansy chrysanthemum, carnation, spiraea, paphiopedilum, Echinops laizfolius, endive, marigold, peony
Tree class	Tea, mulberry, paulownia, poplar, gingko, plane tree
Shrubs class	Kudzu, evonymun alatus, wild jujube
Fish	Carp, oreochromis niloticus
Silkworm class	Silkworm
Livestock	Pigs, cows, sheep
Poultry	Chicken
Forage grass class	Alfalfa, stylosanthes guianensis, flat bullwhip grass, orchard grass, guar, gaodan grass, grain amaranth, quackgrass, ryegrass, siberian wildrye, sweet pea
Lawn class	Turf volume, iris

are an important breakthrough on theory and technology of crop breeding. These systems have made certain achievements in their more than 10 years of development, have shown a strong vitality and have declared their good application prospect, but after all they are still in a spontaneous application stage, so as to limit their further development and expansion. Therefore, their development should pay attention to several questions in future:

First, it is an urgent need to make greater efforts to promote its scopes, making the grey breeding theory become more and more popular. At present, the propaganda of crop grey breeding theories and technological systems also only stay in the stage or level of publishing articles and reporting in the national academic conferences, its influence range is smaller, so there are a lot of room to grow. This requests us to build a strong popularizing team as soon as possible, to instill the grey breeding thinking, to propagate the grey breeding theory and to popularize the grey breeding techniques to breeding units and breeders to which the academic papers and academic meeting don't spread. At the same time, we should carry out joint development and research with the breeding departments of the national famous seed industry group. Only in this way, can we give full play to its guiding role in crop breeding, realize a cross from the traditional experience breeding to quantitative breeding and improve the overall level of crop breeding.

Second, efforts to create a good academic environment and atmosphere extend and expand the grey breeding theory to the international academia, make the theories and technological systems of crop grey breeding gradually towards the world. By various channels and forms such as publishing papers in the international famous academic journals, taking an active part in international academic conferences and cooperating with overseas famous breeding institutes and so on, prompt the grey breeding theory to occupy a position in the palace of international crop breeding science.

Third, constantly absorbe new theory and new achievements, improving crop grey breeding theory to be perfect and mature day by day. Indeed, as a new inter discipline, crop grey breeding science is still in the newborn period, there are such and such deficiencies and problems, as she was composed of many disciplines in the beginning of gestating, still needs the support of the academic disciplines in the process of its further development, more needs new subjects and theories to enrich and perfect. In a fairly long period of time in the future, it is still a research subject and direction to integrate and penetrate with genetics, quantitative genetics, bioinformatics and biotechnology, extension theory, similarity-difference theory, rough set theory, the theory of data mining and many other disciplines. Of course, in the process of mutual fusion and penetration among disciplines, we should pay attention to achieve mastery through a comprehensive, avoid by all means interpret out of context and rotta. Believe the crop grey breeding science will one day be perfected and be yet to mature under the study, care and love of numerous breeders.

ACKNOWLEDGMENT

The relevant researches done in this study are supported by Basic and Forward Technology Foundation in Henan Province (No. 092300410) and Key scientific and technological project of Henan province (No. 112102110001).

REFERENCES

Chen, C., Z. Hu, F. Zhang *et al*., 1999. Application research of grey system theory in the cowpea breeding. Seeds, 1999(5): 3-6. (In Chinese)

Deng, J., 1982. Control problems of grey systems [J]. Syst. Control Lett., 1(5): 288-294.

Guo, R., 1995. Crop Grey Breeding Science. China Agricultural Science and Technology Press, Beijing. (In Chinese)

Guo, R., 2007. Application of grey breeding theory in breeding of Anmai No.1 and Anmai 7. J. Triticeae Crops, 27(1): 20-25. (In Chinese)

Guo, R. and L. Guan, 2005. Retrospect and prospect of crop grey breeding science research. Sci. Technol. Rev., 23(1): 52-55. (In Chinese)

Guo, R. and Z. Wang, 2008. Crop Grey Breeding Computer Decision-making System and Its Application. China Agricultural Science and Technology Press, Beijing. (In Chinese)

Guo, R., G. Xue and C. Song, 1996. Grey theory of wheat breeding process and its application. Foreign Agr. Wheat Crops, 1996(4): 2-4. (In Chinese)

Guo, R., H. Zhan, C. Yang *et al*., 1999a. Discussion of selection methods of parent and its progeny for Luomai No. 4. Triticeae Crops, 19(6): 14-16. (In Chinese)

Guo, R., Y. Wang, S. Wang *et al*., 1999b. The testing and verifying of single - plant grey selection in millet breeding. J. Grey Syst., 11(1): 29-34. (In Chinese)

Guo, R., C. Yang *et al*., 2002. Discussion of techniques and approaches for Anmai No.1. Wheat Res., 23 (3): 17-20. (In Chinese)

Guo, R., J. Li, Z. Lu *et al*., 2006. Breeding techniques and methods of wheat new variety Anmai No.7. J. Henan Agric. Sci., 2006(11): 35-37. (In Chinese)

Guo, R., Z. Lu, Q. Wu and Y. Liu, 2014. Study on technical process for crop grey breeding. J. Grey Syst., 26(2): 11-19.

Hao, Y., Y. Tu, X. Hu *et al*., 2005. Breeding of silkworm new varieties the Ecan no. 3 and Ecan No.4[A]. Proceedings of the 7th Session of the 2nd Board and Academic Conference of China Silkworm Society [C], 2005: 181-184. (In Chinese)

He, L., S. Wang, Q. Shao *et al*., 2004. Application of grey system theory in the cotton breeding. Seeds, 23(7): 66-67. (In Chinese)

Huang, J.H. and G.L. Lu, 2001. Provided a Basis for Cocoon Silk Export - Hubei Academy of Agricultural Sciences Have Bred High-Quality Silkworm New Variety [N]. Hubei Daily, 6/4, A02 Edn., (In Chinese)

Li, W. and S. Chen, 2003. Grey correlation degree analysis of Soybean high yield breeding. J. Agric. Mod., 12: 4-5. (In Chinese)

Liu, S., Y. Dang, Z. Fang and N. Xie, 2010. Grey System Theory and Its Application. Science Press, Beijing. (In Chinese)

Luo, Y., 2009. Breeding and popularization of high quality and super sweet corn the Huameitian 168[D]. South China Agricultural University. (In Chinese)

Wang, K., R. Guo and B. Wang, 2003. Breeding technology and method for Yulv No. 3. Rain Fed Crops, 23(6): 328-330. (In Chinese)

Wang, K., Z. Song, Y. Han *et al*., 2005. Rare black mung bean variety-- Anyang black mung bean No.1. Seed Ind. China, 2005(5): 30. (In Chinese)

Xue, G., R. Guo and C. Song, 1994. Application of theory of single-plant grey selection in wheat breeding. Proceedings of 3rd National Youth Symposium on Crop Genetics and breeding, China Agricultural Science and Technology Press, Beijing, pp: 281-288. (In Chinese)

Yan, Q., F. Luo, X.S. Sun *et al*., 2001. High quality pumpkin variety-Jin Li. J. Chinese Veg., 2001(1): 47-48. (In Chinese)