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## Some critical considerations on rice high-yielding breeding in China

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**Abstract** Views and comments concerning rice high-yielding breeding in China had been touched upon: (1) historical development of rice breeding in China and its prominent contributions recounted; current challenges evolved from rapid population increase, erosion of key natural resources and socioeconomic changes envisaged; (2) concept of extra or super high-yielding rice breeding and related ideas embraced nowadays in the main rice-producing countries assessed; the conception of so-called superrice in China could have been misled and misunderstood, and no substantial genetical differences could be affirmed yet between superrice and modern high-yielding rice; (3) two strategical approaches of rice production and breeding in China would have been persistent in the construction of most favorable-to-growth rice fields to plant rice varieties with high-yielding potentiality as well as renovation and rejuvenation of less favorable rice fields to plant most adaptable-to-ecoenvironment varieties with promising productivity; in addition, breeding for rice varieties compatible with the specific rice regions ridden by adverse ecoenvironments; (4) overview of the relationship between the development of genetical researches and the perspective of rice breeding; integration of the classical genetical principles and breeding methods and techniques wherefrom with molecular biotechniques underscored. Finally, appeal to the breeders to adhere to due attentions to the development of genetics and promote pragmatism and traditional ethic solemnly so as to live up to implementing the national rice breeding mandates.

**Keywords** rice breeding, modern high-yielding rice cultivars, “superrice”, integration of high yield and stability, genetics and traditional breeding, biotechnique

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### 1 Rice breeding in China confronted with challenges

China is an ancient civilized country of rice cultivation, having more than five thousand years of rice cultural history. The age of the carbonized dehulled rice grains unearthed in Giahu relic site, Wuyang, Henan Province, China was 1 000 years earlier than those discovered in Hemudu, Yuyao, Zhejiang Province in the 1970s (Chen et al., 1995).

The improvement of rice has been always undergone a process of alternation of gradual diversification and leap forward, bringing into shaping a better form of cultivated rice. In remote ancient era, the exploitation and employment of wild rice by human being gradually rendered it into kinds of semi-cultivated or cultivated rice by domestication, finally turning out tens of thousands of cultivated rice varieties (cultivars) or prototypes of cultivated rice varieties (primitive cultivars), followed by an flamboyant culture of rice cultivation flourishing in human society. This was a great turning stage ever foreseen in rice evolution on earth.

Rice improvements witnessed progresses with unprecedented advancing paces since earlier the last century. Modern genetics had been established thanks to rediscovery of Mendel's laws in 1900, the improvement of rice varieties has been put on the scientific foundations instead of relying on experiences since then, even empiricalness only. Starting from the early 1920s, institutions of rice improvement were established one after another in China, scattering mainly along the Yangtze River Valley and Southern China at that period, supervised formally later in 1933 by Central Agricultural Experimental Institute in Nanjing. By using the pure line selection method and technique at the advantage of rice selfing characteristic on the incipient stage to employing varietal crossing method and techniques later, lots of improved varieties were developed and primitive land races were supplanted (Zhou, 1948), leading to effectively escalating the yield potential of rice varieties: such as Nante Hao, Shengli Xian, Improved Dongguan Bai, Zhechang No. 1 and No. 9 and Zhongnong 4 and so on. These improved varieties were characterized by earliness, large panicles and tall stature, nevertheless, with yield up to more than 4.5 t/hm<sup>2</sup> compared

with 2.55 t/hm<sup>2</sup> of the national average from 1931 to 1937 (Agriculture Bulletin (1942), 7(16–21): 323–326). We are indebted to pay tribute to our first generation of veteran rice scientists who had contributed outstandingly to lay a modern scientific foundation for rice breeding in China, such as Deng Zhiyi, Dingyin, Zhao Lianfang, Zhou Shilu, Li Xianwen, Xu Guanyin and Hu Zhongzi, and so on, to name a few.

Breeding for semidwarf plant-type rice beginning from the 1950s in China in the wake of discovery and exploitation of a semidwarfing gene *sd-1* led to realizing people's dream of cultivating high-yielding rice without lodging and a solid foundation laid for continuously breeding for ever higher-yielding rice and steadily realizing development of all over rice production. Owing to reduction of rice plant height from tall to semidwarf which led to amelioration in coordinating rice characteristics morphologically and physiologically, a great breakthrough of achieving high yield in rice production was attained, and rice breeders were highly inspired and enlightened. This was a triumphant leap of rice genetical improvement with impacts perpetuating in years to come.

Enlightened by great Charles Darwin's concept about hybrid benefits in the 19th century and the successful exploitations of hybrid heterosis by American corn breeders from the 1920s to the 1930s, relevant principles and techniques were adapted successfully for hybrid rice breeding by rice breeders in China. *Indica* type hybrid rice was first developed followed by *japonica* type hybrid rice at the early 1970s. *Indica* hybrid rice had been rapidly and widely extended for rice production in the main rice areas in China, the productivity of cultivated rice once again has been enhanced significantly. This was another phenomenal leap of rice improvement in China.

Now both increase of food production in general and further improvement of cultivated rice in particular are faced with grim challenges in the wake of steady increase of population, erosion and deterioration of eco-environment and natural resources, global warming as well as prevalence and pervasiveness of severe natural disasters, changes of social economics and people's living patterns and unique demands following rapid economical development in China, and so on.

Realization of a new leap in rice breeding is not easy, stemming from lots of difficulties and obstacles have never been seen before, particularly, so far as theoretical and applied points of view are concerned: genetical mechanism of high-yielding potential is fuzzy or unknown literally, high-yielding genic resources need to be explored and identified; the intimate relationship between high yield and yielding stability has to be regulated and coordinated anew; it turns out to be harder to upgrade the level of productivity of rice varieties simply by empirically pyramiding rice traits through crosses with preferred materials breeders accustomed to, and so on. In short, a new breakthrough of improvement of cultivated rice remains to be explored theoretically and practically.

Chinese population would be expected to reach 1.6 billion in 2030, requiring 6.4 hundred million tons of food supply

each year to feed the people on the basis of 400 kg per capita. It would be quite formidable a mission for us to push the total food production level from 4.3 hundred million tons in 2003 (China Agricultural Year Book, 1986, 1991–2001, 2004) up to 6.4 hundred million tons to meet the people's needs.

In order to ensure a new leap in rice breeding in China, it would be prerequisite to have innovative breeding materials and techniques at hand, rice cultivars in the main ecosystems of rice areas need to be rejuvenated with the goal of guaranteeing steady increase of average yield per unit area and total yield of production to ensure sustainable food security and people's living needs. Crop breeding, being a systematic science with genetics serving as its core foundation, has been interdisciplinarily intertwined with various fields of agricultural and biological sciences, and fostering and training high-quality technicians would be imperative to the boot.

We need to maintain and further strengthen our position in the development of rice science in the world already assured by always keeping every field of researches in tune with each other and moving forward coordinately and harmoniously.

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## 2 Modern high-yielding rice cultivars and "Superrice"

The concept and breeding strategy for super high-yielding rice breeding was initiated by Japanese rice breeders in the 1980s, setting forth a breeding goal of enhancing per unit-area rice yield by 50% within fifteen years starting from 1981 (Tadaaki, 1989). Results by Japanese rice scientists convinced rice breeders all over the world that rice yielding potentiality could be significantly promoted and exploited through genetical improvement for human welfares.

Rice scientists in International Rice Research Institute (IRRI) put forth new plant-type project (NPT) in pursuing rice high-yielding breeding in 1989 with the breeding goal of enhancing the yielding level of rice varieties up to 13–15 t/hm<sup>2</sup> (IRRI Toward 2000 and Beyond, 1989) in comparison with current 9 t/hm<sup>2</sup> in IRRI, Manila. The NPT rice had been designed as semidwarf, big-panicled and few tillers without non-functional tillers. The IRRI breeders stressed on combination and integration of yielding potential with yielding stability by incorporating unique genes resistant to diseases and pests and tolerant to abiotic stresses, in conformity to the particulate ecoclimatic environments prevailing in Southeastern Asia area (IRRI 2005-2007 Midterm Plan).

The super high-yielding rice breeding project was initiated in the earlier 1990s in China based on Chinese specific national conditions. Chinese breeders stressed on high-yielding potential of the super high-yielding varieties supplemented with characteristics of modest resistance to diseases and grain quality. In the late 1990s, however, the so-called "superrice" was coined from nowhere, and "superrice research project" was formally promulgated in 1996 by Chinese Ministry of Agriculture, and implemented gradually nationwide. Goals of researches during the period from 2000 to 2015 were

elaborated specifically: yield potential of “superrice” in 2000 was projected to reach 10.5 and 12 t/hm<sup>2</sup> in 2005, and 13.5 t/hm<sup>2</sup> in 2015 (Division of Science, Technology and Education, Ministry of Agriculture. Plan of Research and Extension of Chinese superrice (2005–2010). 2005), (Cheng et al., 1998). Majority of Chinese breeders and rice experts all over the country seemingly embraced and accepted the idea of so-called superrice, and lots of theoretical and practical viewpoints and comments concerning the breeding goals and morphological and physiological characterization of characters and traits have been put forth and discussed (Yang, 1987; Huang, 1990; Yang et al., 1996; Cheng et al., 1998; Yang, 2000; Huang, 2001; Zou and Lu, 2005), but no genetical definition and dissections had been offered at the least.

What is “superrice” after all? How to define it from the classical breeding concept? How to differentiate the so-called superrice from modern semidwarf high-yielding rice?

Modern semidwarf high-yielding rice cultivars (briefly MSHR), incorporated with *sd-1* as its pivotal background and characterized by semidwarf plant height with multiple panicles, harmonious panicle-grain interdepece, high efficiency of light exploitation, and high harvest index and yielding potentiality, has been recognized as a modern new variety of cultivated rice, which still dominated rice productions in the main rice-growing areas all over the world so far, and has deserved a particular place in the history of rice breeding.

In the early 1970s, hybrid rice (HR) had been successfully developed and rapidly expanded for productions in South China, thanks to the discovery and manipulation of cytoplasmic or nuclear sterile genes and restorer genes. Seeds of hybrid rice needed for sowing each time must be produced in advance with special methods and techniques in the field of hybrid seed production. The seeds of hybrid rice, being F<sub>1</sub>, is highly uniform in genic constitution but heterozygous, people already used to call it hybrid rice although different from varieties bred by hybridization in meaning.

Thus far, the key genetic constitutions of MSHR and HR could be basically defined and discriminated explicitly. They benefited in exploiting better plant type in common; they were incorporated with well-known major genes conferring fertility and prolificity, resistance to diseases and insect pests and grain quality; and they could be benefited from optimistic effects of genic interactions, and the like (Shen et al., 1965; Aquino and Jennings, 1966; Zhu et al., 1980; Li and Yuan, 1986; Zhu et al., 1995; Khush, 1997; Crow, 2000; Khush and Brar, 2000).

Contrarily, it could not genetically define the genetical buildups of the much-ballyhooed “superrice” variety and “super hybrid rice” at least now in China. There would be no substantial differences in terms of breeding principles and strategies in conducting breeding modern high-yielding variety and “superrice”. They are of *indica* or *japonica* backdrop, even if germplasmic introgression could artificially take place; they are incorporated with the same or allelic semidwarfing gene, *sd-1*, especially in case of *indica*-type

varieties and “super hybrid rice”, and the like. As to yielding performances, there could be overlapped in absolute yield on unit area of cultivation under most favorable conditions in conformity to respective requirements. An *indica*-type variety, Guichao, bred by Guangdong Academy of Agricultural Science in the 1970s can be taken for serious comparative considerations. Grown under the particular ecoenvironmental conditions in Yunnan plateau, Guichao could produce astonishingly rough rice more than 15 t/hm<sup>2</sup> (Yuan et al., 2000), and under intensive cultivations 10–12 t/hm<sup>2</sup> could be produced in other favorable places. Similarly did other *indica*-type varieties, Teqing and Shengyou, for example, bred also by the fore-mentioned institution in the 1980s and 1990s respectively. More similar events would be seen elsewhere. Why would not they be called “superrice” according to the standards promulgated? But they were conventional high-yielding cultivars, no need to call it “superrice”. It does not mean that there are no differences between MSHR and so-called “superrice”, but that the breeding technological route pursued by rice breeders and upgraded incessantly in China ever since the 1920s had been proved effective, and dovetailed entirely in classical genetical basic principles.

Rice high-yielding is a composite character symbolically, in which every component character and trait would be interdependent, ameleoration of anyone literally might trigger changes in yielding performance. It would be realistic to conceive and admit that our rice breeders by exploiting the rice germplasms and resources from all over the world and summing up breeding experiences accumulated from productive practices, on the basis of semidwarf plant-type, mastered to tailor and optimize the structure of population and panicle-grain interrelation harmoniously that led to promotion of capacity for rice plant to assimilate sunlight so as to reach the point that varietal comprehensive qualities would be further improved.

Given the complexities of yielding potentiality which would have been controlled by major as well as sets of quantitative genes and affected by other factors, the so-called high-yielding gene(s) probably might not exist, searching for such gene(s) would be doomed to failure. So far, any specific and elite gene has not been identified or exploited effectively which would help make a further breakthrough of current yielding ceiling. Since no substantial distinctions genetically and physiologically differentiate “superrice” from MSHR, would it necessitate the title “super” bestowed on a variety for the sake of touting its so-called superiority?

Touting “superrice” in the community of rice science and in marketing would make misleading and misunderstanding. Is “superrice” a particulate cultivar type controlled genetically by particulate gene(s)? No. Is “superrice” the best ever rice variety? No. The high-yielding character is relative, perpetuating dynamic changes depending on time-space relationship. High-yielding could not be absolutized so as to say “superrice” a kind of best ever rice cultivars.

In retrospect, the history of rice production in China revealed that from the 1930s to 1950s before the founding of

People's Republic of China, the national rice average yield had been less than 3 t/hm<sup>2</sup> (Agriculture Bulletin (1942), 7(16–21): 323–326), in the 1950s it was catapulted to 6 t/hm<sup>2</sup>, wherein variety improvement played a key role, along with it, people's concept of high yield was changed. Whether a variety is depicted as “good” or “bad” is relative, also true even if a variety had been luckily endowed with combination of yield, resistance, quality and adaptability. Absolutization of appraising rice variety contradicts the practical reality and scientific perception. Unfortunately, high-yielding varieties created by scientific methods and based on scientific principles have been ironically tagged commercially by self-sought objectives right now. In this context, from the standpoint of scientific conscience and our traditional ethic, it would be better not to call high-yielding or super high-yielding varieties and hybrid rice “superrice”, which actually are affiliated to modern semidwarf high-yielding varieties or hybrid rice, not beyond, period.

### 3 Adhesion to reality in variety development and exploitation

In concordance with the national status and realities of rice production, constructing most favorable- to-high-and-stable-yielding rice fields, to which high and super high-yielding varieties with diverse characteristics are planted on the one hand, renovating and rejuvenating intermediate-and-low-yielding rice fields, to which high-yielding and adaptable varieties are planted on the other hand, would be the solid way to ensure balanced and sustainable increase of rice production in the long run in China. Both should be bolstered generously by huge input economically. However, high-yielding varieties should be diversified conforming to specific requirements and adaptability especially underscored because of the severe constraints encountered usually in the intermediate-and-low-yielding rice fields.

High-yielding potential combined with stability should be emphasized for any high-yielding rice varieties, especially the super high-yielding varieties. No stability could amount to no high yield at all. Practices and experiences of rice production compellingly revealed that yield-related characters proved to be endemic to unique ecoenvironments, fluctuating along with the environmental changes. Rice varieties characterized by big and dense panicles would have had problems of sticking to technologically stringent requirements, for instance, the level of yielding performance would easily fluctuate, depending on time, locality, and human manipulation. “Superrice”, being big-panicked, scarce-tillered, and strong-stawed, must be endowed with adaptability, in particular, otherwise, input and output could be at odds, or too costly to be benefited, winding up worthless altogether.

Any character of cultivated rice, being evolved phylogenetically from natural and artificial selections, would be inherited with ecological weights with which breeders are concerned. For instance, panicle-type of rice varieties is one

of the most fascinating characters, which diversified conspicuously to adapt it to specific ecoregions to ensure achieving satisfactory harvest. Normally, straight-panicked rice varieties would be favorably adapted to ecoenvironments in North and Northeast rice areas of China, wherein more panicles could be accommodated on unit area of growth due relatively to less precipitation and atmospheric humidity. Whereas in the Mid-and-Lower Valley of Yangtze River, straight-panicked varieties would be vulnerable to attack, ravaged by such diseases as neck and grain blasts (*Pyricularia oryzae*) and false smut (*Ustilaginoidea virens*) favored by high humidity during heading and maturing, modestly bended and semisparsely-panicked varieties would be preferred there, although panicle type *per se* would not have to be correlated directly to yield potential.

Dynamic equilibrium of panicle-grain relation is closely linked not only to the number of grains on unit area and space, but to tillering and development of root systems, increment of biomass and autoregulation of growth space of rice populations. Tillering is an important trait with multiple biological functions for cereal crops. Sterile tillers would not necessarily be useless biologically. Breeding for rice varieties with scarce, even void of tillers, as some breeders claim, will run afoul with biological functions for normal development of rice plants. Utilization of such varieties for getting high yield will be overwhelmed by extra input economically and technologically.

We should spare no effort to promote fertility and plump-seed-setting rate for high-yielding rice varieties, even if an increase by one or two percent will be conducive to bumper harvest. Rice variety typified by big panicles and low seed-setting would betray its physiological defects and render it less beneficially or uselessly, and would be physiologically-defected. It is not that the bigger the panicle, the better; but that the bigger the panicle, the higher the seed-setting should be.

We should take rural economic development status into account in extending high-yielding varieties to farmers. In the wake of rapid national economical development and exodus of rural labour to cities, farmers would welcome rice varieties which could be more amenable to achieve high yield without high cost. “Superrice” and “super hybrid rice” would tend to require high level of fertilizer input to ensure high yield, less resilient in autoregulation of population structure in response to environmental fluctuations, in addition, physiologically source-flow-sink dynamic equilibrium of rice plants and populations would be so intricate to be manipulated by technicians and farmers. In this context, training of grassroot technicians and farmers appears to be imperative so as to cope with popularizing high-yielding and super high-yielding varieties to farmers. Modern rice production, as matter of fact, is a systematic engineering in which technique-awarded technicians and farmers will be one key component.

Problems stemming from coordinating high yield and yield stability would be closely linked to issues concerning protection of eco-environmental resources. Rice production

should not be benefited at the expense of deteriorating soil fertility and polluting environment. We should always respect and learn from farmers who, being settled for generations on their native lands, are most familiar with local situation and its twists and turns. Our farmers have long been accredited to be realistic, leaving nothing to chances. We should be reminded that high-yielding varieties and *indica*-type hybrid rice bred by our rice breeders ever since the 1960s and 1970s by means of plant-type breeding, inherently incorporated with high yielding potential and adaptability, were amenable to achieve productive goals by farmers in the main rice areas in China, the historical legacy should be bequeathed.

Intermediate-and-low-yielding fields accounted for 80% of 100 million hectares of arable lands in China (Jin, 1981), more than one half of lands were short of irrigated facilities (Chen, 1998), that the status of reaping food at the mercy of "heaven" had not been radically changed, alas. For example, vast terrain fields spreading over the Hengduan Mountain Range in Southwest China are all rain-fed fields, wherein rice production is always grim. Lots of hillside fields and flat fields intercalated in mountains in the Lingnan Mountain Range were vulnerable to drought and flood alternatively. We have, in addition, vast areas of lands lying malnourished or barren, and the like. Huge potential of food production would be anticipated in these fields and remain to be assessed. It needs, however, to be exploited and renovated by huge economic input and sophisticated dedications. Variety improvement for those areas should be stressed on adaptability and stability accordingly. In short, we should be always realistic and prudent in dealing with rice production in such areas responsibly.

Improvement of cultivated rice by human wisdom would never come to an end. There will be no need and probably impossible to breed rice varieties incorporated with all imaginable desirable characteristics, but high-yielding potential, stable performance and better palatability, and low cost for production would be required in common for the long run.

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#### 4 Rice breeding and development of genetics

Rice breeding has been closely linked to the development of genetics, and the relationship between them has been further tightened as researches in molecular biology and biotechniques have been spilling into various fields of rice breeding in recent decades. Now theoretical elaborations and techniques have provided innovative probes and measures for rice breeding. Trailblazing work has been done in genic mapping and genome sequencing, rice scientific mysteries imbedded in the genome have been cracked, the mechanism of high-yielding which has been thought to be controlled by major and minor genes and interacted with environments could be expected to be unraveled, quantitative trait loci (QTL) traced and mapped by molecular biological methods combined with statistical logic analysis in depth tracing would be ensued

(Ikehashi and Araki, 1984; Lander and Botstein, 1989; Gale et al., 1996; Li, 1999; Gale et al., 2001; Li, 2001; McCouch et al., 2002; Mo, 2003). An exciting panorama has unfurled before us to quest for messages desperately needed for rice breeding.

Breeding for high-yielding varieties has proved to be a most effective and economical approach for sustainable increase of rice yield all over the world. Since rice dry matter is synthesized by photosynthesis in capturing sunlight, rice high-yielding breeding, in essence, is succeeding development of plant-type breeding. Synergistical forward and reverse genetical researches bolstered by interdisciplinary studies would be expected to come to a new breakthrough in rice breeding.  $C_4$  crops, exemplified by corn and sorghum, have been known to be superior to  $C_3$  rice in photosynthetic efficiency, and according to IRRI,  $C_4$  rice lines derived from genic engineering may yield up to 15 t/hm<sup>2</sup> under tropical circumstance. Rice, being a small-planted crop, in contrast with large-planted crop, corn and sorghum, could take advantages of the capability of enlarging population by profuse tillering per unit area to ensure capturing as much incident light as possible for biomass buildup, particularly in the North and Northeast rice areas in China. In Southern China rice area, where double rice cropping prevailed traditionally, it has been emphasized since the 1980s to achieve early growth and expansion of leaf index prior to the inception of high temperature and strong sunlight from climatic changes. Rice breeding in the long run in China would be directed toward breeding for a new variety of rice incorporated inherently with high efficiencies in photosynthetic ability, fixation of carbon dioxide and harmonious translocation and allocation of assimilates by integrating elite germplasms and on the basis of further improving plant type.

Exploitation of hybrid vigour (heterosis) was a great creation in the history of crop breeding dated back to Darwin's era. Persistent researches and breeding exercises since the early 20th century had revealed that the genetical mechanism of hybrid vigour most probably resided in specific allelic interactions of genes leading to beneficial biological effects from dominance and overdominance (Crow, 2000). The level of hybrid vigour had been shown to be related to genetical distance between two parents. Generally, the larger the distance, the higher the vigour, but not the larger the distance, the better. Critical points would hinge on making clear the homologies and specificities of allelic interactions between related genomes, so as to lay a solid theoretical foundation for achieving a high level of hybrid vigour and realizing a leap of yielding potential.

Evolution and diversification of cereal plants had withstood a tortuous process of about 60 million years (Gale et al., 2001). Recent researches have revealed the presence of homology, similarity and synteny among the genomes of cultivated rice and cereal crops (Gale et al., 1996; Gale et al., 2001), wherein similarity in genes, genic constitutions and orientation had been reported. Array of alleles or homoellogical alleles or analogs would be expected. Searching

for genes needed for breeding high-yielding potential and other beneficial characters prompts imminently genetical dissection of its allelism, interrelationship within gene families and genetical functions. Blindness and aimlessness in selecting parental diversities for use in rice breeding would be avoided therefrom.

Since the 1950s, exploitation of subspecific germplasms has been weighted by rice breeders domestically and abroad with a view to enrich and strengthen genetical basis. The primary obstacle therein has long been witnessed to be poor fertility and semisterility of intersubspecific hybrids. This problem has not been solved radically so far. Probably, construction of a harmonious and compatible genetical background would be involved. Fertility of intersubspecific hybrids from *indica* × *japonica* could be raised or gradually recovered by back crossing or multiple crossing that might be linked to readjustability and regulation of genic relationship to promote recovery of harmonious genetical background, but inevitably and unintentionally, maybe, at the sacrifice of rogueing desirable gene(s). In the 1980s, the so-called wide compatible gene, *S-5<sup>n</sup>*, located in chromosome 6, was discovered by Japanese rice scientists which triggered a series of studies later in China (Ikehashi and Araki, 1984; Ikehashi and Araki, 1986; Zhang and Lu, 1987; Zou et al., 1989; Lu and Zhang, 1992; Wan et al., 1993; Wan and Ikehashi, 1996). *S-5<sup>n</sup>* was proved to be effective to promote the fertility of hybrids between *indica* and *japonica* varieties under certain circumstances through interallelic reaction in *S-5* locus. However, the semisterility encountered in subspecific hybridizations, being extraordinarily complicated, *per se*, could hardly be overcome satisfactorily by counting on individual genes, so more studies would be necessary. Some much ballyhooed varieties and hybrid rice allegedly bred through intersubspecific hybridization need to be genetically dissected in order not only to upgrade people's knowhows but to benefit follow-up studies.

A high-yielding breeding concept of "vigour and plant-type combined" put forth by professor Yang since the late 1980s (Yang, 1987; 2000) has been appreciated by rice breeders in China. In case of hybrid rice breeding this concept would be readily understood, but not in breeding for varieties. On occasion of breeding for "superrice" varieties, being homozygous in genetical constitution, there would be no way to extract the so-called vigour emanated from heteroallelic interactions, actually  $[h] = 0$ , in accordance with classical genetical principles (Mather and Jinks, 1977). The so-called vigour here would be no more than preponderance over parents, originated probably from character complementations or nonallelic interactions, especially in case of intersubspecific hybridization. In addition, the so-called cyto-nucleic hybrids, no matter cytoplasm of hybrid coming from *indica* and nuclei coming from *japonica*, or *vice versa*, have been justified to have nothing to do with hybrid vigour.

In view of the advantages of hybrid rice breeding in exploiting simultaneously the allelic and nonallelic interactions of genes, hybrid rice breeding would entertain preponderances over breeding for varieties conventionally,

thus, exploitation of  $F_1$  hybrid vigour would constitute a most reliable approach for super high-yielding breeding. However, it would be easier for conventional breeding to coordinate and regulate preponderance combined with plant type. From breeding strategical standpoint, two approaches of rice breeding, conventional and hybrid rice breeding, would be complementarily and beneficially coordinated to contribute to safeguard the key position of rice production in sustaining food security in China.

In the matter of fact, it is nothing but depending on intersubspecific or interspecific hybridizations for rice breeders to implement research projects of breeding high or super higher-yielding varieties. It would be a delusion. It will become more apparent so long as genomics researches of cultivated rice and its near relatives go on deeper. It was estimated that about 100–120 thousands of rice varieties had been used for rice production all over the world (Chang and Li, 1991; Pathak and Saxena, 1980). Rice germplasms are so diversified and rich that almost no morphological and ecophysiological traits and characteristics could be fetched wherefrom, more unique and diverse rice germplasms will be created following the development of conventional and unconventional techniques to engender desirable breeding materials that rice breeders crave for. Traditionally-called conventional breeding nowadays will have upgraded and imbued with new meanings.

In retrospect, many high and super high-yielding varieties were bred with the method of intervarietal breeding. Guichao and Teqing were well-known. Lemont (US Rice Journal, 1983, 86(5): 10) and Carlepearl (Hu, 1983) bred by American rice breeders, which could yield 12 and 11 t/hm<sup>2</sup>, respectively. Super high-yielding varieties bred by Japanese rice breeders in the 1980s were not necessarily from intersubspecific crosses also, and so on. Such high-yielding varieties will be developed likewise in the years to come continuously.

Genetics provides most important fundamental theories for crop breeding. Recent history of rice breeding, to be blunt, was one guided by classical genetical theories. Starting from Kuwada's establishment that cultivated rice is diploid with somatic chromosome number  $2n = 24$  in 1909; Parnell's first report on rice genic linkage in 1917; Takahashi's first classical map of genic linkage in 1963 (Takahashi, 1964); McCouch's establishment of the first molecular genetical map of linkage in 1988 (McCouch et al., 1988); uniform chromosome numbering established in 1990; Harushima's establishment of the first high density molecular genetical linkage map in 1998 (Harushima et al., 1998), to the recent publications of a draft sequence of *indica* and *japonica* rice genomes by Yu et al. (2002) and Goff et al. (2002), respectively, screening and identification of useful genes and establishment of effective breeding methods, construction and improvement of genetical populations, realization of breakthroughs in breeding high-yielding varieties as well as establishment of techniques and systems for seed multiplication, and so on, all abode by or based on classical genetical principles including quantitative genetical theories without exception.

Molecular genetical theories and biotechniques ushered in an unprecedented era of rice breeding (Khush and Brar, 2000). Nevertheless, rice researches and breeding practices proved that gene screening and cloning by biotechnical methods, marker-aid selection and transgenic breeding studies and so on all have to be combined and integrated with classical breeding in some ways so as to reap practical results. In spite of single techniques and measures sounded usually valuable for specific breeding goal, achievement of breeding for high-yielding and adaptable varieties hanged on interdisciplinary researches associated with various fields of agricultural and biological sciences. There would be a long trek, if not impossible, to create miracle in rice breeding by resorting to over-estimated so-called molecular breeding, supposedly disregarding conventional breeding procedures. Apparently, rice breeding would be inconceivable once isolated from the indispensable field breeding practices.

Be realistic and pragmatic anytime in rice breeding, staying away from arrogance and frivolousness as claiming so-called “world lead”, “extraordinary breakthrough” in rice breeding, and the like; always being modest and circumspect, adhering due attentions to genuineness and precision in speeches and writing. Dedicating to comply with national ethic and demeanour fostered by our founders of everlasting splendid traditional cultures, and incessantly contributing to the development of rice breeding in the world would be consequential anyway.

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