LITERATURE REVIEW

New Plant Type

The demand for rice is continuously increasing, making the researchers continue to search for and breed new varieties with higher yields. In Indonesia, breeding program to increase yield potential follows two approaches development of hybrid rice and new plant type (NPT) with productivity estimation up to 10 - 20% higher than existing rice varieties (Suhartatik 2003). Agronomically, grain yield is determined from yield components, namely: the number of panicles, number of grains per panicle, percentage of grain filled out, and 1000 grain weight (Yoshida 1981).

The NPT breeding programs have been initiated by IRRI since 1989 (Khush 2000). NPT has important characters, namely (a) small number of tillers (7 - 12 tillers per hill) and all are productive, (b) longer panicles and dense spikelets (> 300 grains per panicle), (c) large and sturdy stems, (d) erect, thick, and dark green leaves, and (e) long and thick roots. The potential yield of NPT is 10 - 25% higher than the common yielding varieties (Las et al. 2003). These characters are in accordance to morphological criteria of the rice plant that will produce high yield according to Siregar (1981), including upright leaves (leaf angle ± 30°), dark green leaf color, and sturdy stems. Erect leaves allow sunlight to reach the entire surface of the leaf. Abdullah et al. (2008) stated that the NPT, specially for irrigated land is necessary to be developed because: (1) irrigated rice is still the main supplier of the national rice production, so planting of NPT will increase productivity, production and farmer’s income, and (2) seed of NPT, which is an inbred rice variety can be easily produced so that the prices of seed will be more affordable for farmers.

The program of NPT rice development in Indonesia started in 1995. Genetic materials used as the parents crossing were introduced from IRRI NPT varieties, local varieties improved varieties, elite lines, and wild rice. Standard selections methods in plant breeding that have been used for the development of NPT are pedigree, bulk, a combination of both, and recurrent selection. Anther
culture methods have also been used to develop pure line more rapidly through the formation of double haploid plants (Abdullah et al. 2008).

From more than 3000 cross combinations, three varieties of semi new plant types (SNPT) have been released, namely Cimelati (2001), Gilirang (2002), and Ciapus (2003) as well as a new high yielding new plant type (HYV), Fatmawati (2003). Fatmawati is a progeny of a single cross between upland rice, BP68C-MR-4-2, with sturdy stem and deep roots and Maros. Fatmawati has strong stems, medium number of productive tillers (8-14 stems) with total grain 200-400 grains per panicle, resistant to brown plant hopper biotype 2 and 3, resistant to bacteria leaf blight disease (BLB) strain 3, the range of yield 6 - 9 t.ha⁻¹ and has tender texture, amylose content of 23% (Suprihatno et al. 2006). However, NPT varieties have high unfilled grains, susceptible to major pests and diseases, such as brown plant hopper, stem borer and gall midge, as well as major diseases, such as bacterial leaf blight and tungro. Yang et al. (2007) stated that the average yields of NPT were still lower than hybrid rice. This is because the hybrids produce more number of filled grains per panicle and per m².

Several promising lines that have uniformity, low number of unfilled grains, more resistant to pests’ major diseases, and good grain quality, are BP360E-MR-79-PN-2, BP205D-KN-78-1-8, BP138F-KN-23, and BP-355E-MR 45 lines. The four lines are proposed to be released as new varieties (Abdullah et al. 2008).

IR64 and other varieties have been improved for NPT by crossing between indica types; NPTs have also been developed through the cross between javanica (tropical japonica) rice with japonica types. Javanica parents were used because they have a long and dense panicle, less tillers, solid stems and vigorous root system. However japonica rice grain has a rounded shape, while consumer in the tropics prefer slender grains. NPT lines that are resistant to major pests and diseases, such as brown plant hoppers, green leaf hoppers, tungro, blast and leaf blight derived from crosses with indica rice have been obtained through backcross and selection methods with molecular marker-aided (MAS) (Khush 2000).

Although NPTs have long panicle, they have small number of tillers, and lodging resistant, but grain yield are low. The small number of tillers decreases
the production of biomass (Peng et al. 1999). This small number of tillers and 
vulnerable to pest attack was suspected to be the main factors causing lower yield 
(Peng and Khush 2003). Since 1995, the International Rice Research Institute 
(IRRI) began to breed the second generation of NPTs by crossing between elite 
tropical japonica varieties with indica varieties. NPTs improvement is aimed to 
increase the percentage of filled grain and high biomass production. Improvement 
of the second-generation NPT has been initiated to increase number of productive 
tillers and number of filled grain per panicle and total biomass production 
compared with inbred varieties indica, IR72. Number of productive tillers and 
number of grains per panicle were a key to develop the second generation NPT 
lines, so that the target of increasing yield up to 10% could be achieved (Peng et 
al. 1999; Peng et al. 2008).

Grain Quality

Development of new varieties has not intended only to obtain high 
yielding varieties but also for grain quality. Good grain quality of rice varieties 
will increase demand and price of these varieties. Criteria of grain quality of rice 
in the international market are: (1) the color of husk; (2) the size, shape, weight, 
uniformity and general appearance; (3) yield and milling degree; (4) chalkiness 
and color; (5) cooking characteristics, taste, and processing; and (6) cleanliness, 
integrity, and purity. Quality of rice can be classified as a physical quality, 
the quality of rice into four, there were: (1) the milled quality; (2) cooking quality 
and processing; (3) the nutrition quality; and (4) have standards of cleanliness and 
purity. The quality of rice is influenced by several factors, namely: (1) genetics, 
(2) environmental condition and pre-harvest activities, (3) treatments during 
harvesting and (4) post-harvest treatment (Damardjati 1987).

When the hulls are removed from rough rice it becomes brown rice. 
However, not all dehulled rice was brown in color. The outer bran layer of the 
grain and embryo (germ) gives various grain color and can vary from light yellow 
to red and to dark and purplish black. Rice bran and germ contains greater
amounts of dietary fiber, vitamins, minerals and other health-related components than the white center portion of the kernel (endosperm).

Consumers prefer rice grains that are transparent and not chalky. Chalky areas of the grain are a result of air spaces in between the starch granules that make up the endosperm. Variation in kernel whiteness and transparency can be due to differences in rice varieties, cultural management methods, weather conditions during the crop year, and storage conditions of the harvested rice. Milling rice resulted in a loss of vitamins, minerals and dietary fiber. In less developed countries, where rice is major component of the people’s diet, such nutritional losses may significantly impact human health (Bergman et al. 2006).

Taste and cooking quality are generally determined by consumer subjectivity. It differs among ethnic, environmental condition, education, employment and income. Assessment of the characteristics of rice consumers was positively correlated to the price of rice and based on the physical properties of rice (white degree, the percentage of head rice, rice grain size and chalkiness) and the nature of such gel consistency, but negatively correlated with levels of amylose (Suimon et al. 2003). In the tropics, consumers prefer rice having grains that are long, slim (slender) and low amylose content and gelatinization temperature levels (intermediate). Rice with these characters will be soft and sticky when cooked. Short sized rice grains, with low amylose content and low gelatinization temperatures will be sticky or tender when cooked and preferable in Japan, Korea, and China (Kush 2000).

Grouping of rice based on amylose content does not only represent consumers preferences in determining the texture of rice but also as reflect their reference in selecting rice for raw materials in food industry. Types of rice used for the manufacture of processed foods differ, depending on amylose-amylopectin contents. Sticky texture is suitable for baby food, while hard texture is suitable for rice noodles, fried rice, and crackers (Suimon et al. 2003; Haryadi 2008).
Aromatic Rice

Productivity and quality of aromatic rice depend on the environmental conditions where rice is grown and managed. Basmati varieties will be more aromatic if the temperature is relatively cool during the growing period in the day time (25 - 32°C) and night (20 - 25°C) with humidity of 70 - 80% during primordial and grain filling stage (Singh 2000). If Basmati is grown in another environment outside the region or at higher temperature, it will not be aromatic (Oad et al. 2006). Grain types, environmental condition and cultivation method are the main factor affecting the productivity but not on aspects determining quality such as aroma and taste. Farmers have their own perceptions about the factors that influence the aroma of aromatic rice that is shown in Appendix 1 (Rohilla et al. 2000).

In the United Stated, approximately 9.5% of its citizens consume aromatic jasmine rice and Basmati. Breeding programs in the United Stated led to the development of aromatic rice varieties, as a result some varieties have been released, namely Della (1971), Dellmont (1992), Dellrose (1995), Dellmati (1998), Calmati 201 (1999), and Sierra (2002). These varieties contain aroma compounds 2-acetyl-1-pyrroline (2AP) and have long and slender grain like Basmati (Moldenhauer et al. 2004).

Rice aroma manipulated by application of essence (chemicals) can easily evaporate. There are more than 114 compounds found in aromatic rice grains (Weber et al. 2000). The main compounds that cause 2AP aroma are detected in one of the famous aromatic rice Khaw Dawk Mali-105 (Bourgis et al. 2008; Laksanalamai and Ilangantileke 1993). Weber et al. (2000) stated that 2AP content of aromatic rice 15 times greater than that of non-aromatic rice. Genes that affect the level of 2AP compounds expression is OsBADH2 (Niu et al. 2008).

The presence of 2AP compounds can be identified through the use of gas chromatography-mass spectrometry (GC-MS) of milled rice. The smell can also be tested from the leaves using 1.7% KOH solution with the smell and taste of rice (sensory test). The research of Hien et al. (2006) showed that the presence of compounds 2AP analysis using GC-MS method did not correlate with the sensory test. There are 12 varieties of aromatic rice containing very low 2AP (0 - 10 ppb)
than it should be between 200-450 ppb as in Khao Dawk Mali 105 and Jasmine rices. This is probably due to a combination of other compounds in addition to 2AP aroma forming.

The aroma can also be detected at the time of rice plants flowering in the field. Smelling the leaves and chewing the seeds is one of the most commonly used to quickly identify the aromatic rice varieties in the field. Aromatic compounds found other than grains are in leaves (Dong et al. 2001).

**Genotype x Environment Interaction**

Interaction between G x E as a source of phenotypic variability, play an important role in the development and evolution of plants. Breeders can make selection of varieties grown in different environments to select adaptable cultivars. Cultivars which have a similar performance in different environments can produce a similarly high yield in other environments (Soemartono et al. 1992).

Environments are divided into two: micro and macro environments. Micro environment is the immediate environment of a plant or the environment of an individual plant against other plants that grow in adjacent place at the same time. Macro environment is the micro environment of the population, the environment-related general location and extent of a certain period, e.g. one season (Soemartono et al. 1992). The environmental influences on plant growth and the feedback/response of each genotype to environmental changes are a reason for special studies of G x E interaction. Studies were evaluated by researchers, among others by the Finlay-Wilkinson 1963, Eberhart-Russell in 1966, and Freeman and Perkins in 1971. The interaction was complicated because of varied components of the environmental factors (Pervin et al. 2007; Ashraf et al. 2001; Rasyad and Anhar 2007).

According to Rasyad and Anhar (2007) the components of the variability of G x E interaction results in greater contribution to the differences in the characters compared to the locations diversity. This gives an indication of instability differences in response of varieties to different environments. In this
way, farmers are expected to be careful in determining which cultivars will be planted in their area.

The existence of G × E interaction can lead to difficulties in breeding program because it could hinder the progress of selection and often interfere in the selection of superior varieties in a trial (Eberhart and Russell 1966). It is often difficult to legitimate deduction in the extensive environmental range (Nasrullah 1981). Analysis of G × E interaction was used to estimate how much adaptability and stability of a variety if planted in the different environment (Mangoendidjojo 2000).

Phenotype stability is dependent upon plant’s ability to determine its response in different environments. Simple method used to analyze the stability of the various experiments was proposed by Finlay-Wilkinson (Haryanto et al. 2008) and Eberhart-Russell (Dushyanthakumar and Shadadshari 2007; Zen 2007; Azar et al. 2008). Adaptability and stability parameters used are regression coefficients ($b_i$), deviation of regression ($S^2_{di}$), and the average results of the genotype. Finlay-Wilkinson assessed the adaptability of genotypes based on the regression coefficient ($b_i$) and mean of genotypes yield. Relationship between yield and location is indicated by the regression line from each genotype and the average results from all genotypes. Then, the regression line result of each genotype compared with the average result of all genotypes from all locations to determine the stability of the results for each genotype. The Eberhart-Russell regression coefficient ($b_i$) and the deviation of regression ($S^2_{di}$) can be used to test the adaptability and yield stability (Lin et al. 1986; Haryanto et al. 2008). A genotype is said to be stable when the value of regression coefficient ($b_i$) was not significantly different from the one and the deviation of regression ($S^2_{di}$) was not different from zero based on t-test (Singh and Chaudary 1979).

Adaptability is the ability of plants to adapt to the environmental conditions of growth. Cultivars are able to adapt to the broad environment, means that the interactions of G x E are small. While the narrow adaptation the variety performance good in such environment but not in other environments. This means that there is interaction G x E is large (Soemartono et al. 1992).
Aromatic rice has different stability and adaptability to various environments. Haryanto et al. (2008) examined nine aromatic rice genotypes from crossing between aromatic rice upland, Mentikwangi and Poso. The results showed several genotypes have a high yield stability and wide adaptability. But there were only several genotypes were well adapted to specific locations.

AMMI Methods (Additive Main Effects and Interaction Multiplication) widely used for analyzing G x E interactions in rice (Mahalingam et al. 2006), wheat (Farshadar 2008), and cotton (Naveed et al. 2007). AMMI is very effective to explain the genotype interaction with that environment. Degradation effect of interactions is done by bilinear models, so the genotypes can be mapped clearly. Biplot clearly maps genotype and environment interaction simultaneously.

There are three main benefits of the use of AMMI analysis. First, it can be used as a preliminary analysis to find a more appropriate model. Second, it can explain the G x E interaction. AMMI with biplot summarizes the pattern of relationships between genotype, between the environment, and between genotypes and environments. Third is to improve the accuracy of the usefulness of the alleged response of G x E interaction. This can be accomplished if only a few real components of AMMI that are significant and does not cover the entire sum of squares of interaction. With least significant component means that the remaining sums of squares are just error (noise). Removing this error will result in more accurate estimate of response of genotype x environment interaction (Sumertajaya 2007).