# CHAPTER 2
# LITERATURE REVIEW

## 2.1 PURPLE GLUTINOUS RICE

Purple glutinous rice or black rice contains pigments, which are located in the aleurone layer as a mixture of anthocyanins. Anthocyanins are subclass of natural phenolic compounds that are widely spread in food of vegetal origin. There are over 250 natural anthocyanins (Kahkonen and  Heinonen, 2003; Francis, 1989). The two major anthocyanins in the extract from aleurone layer of black rice were cyanidin-3-glucoside and peonidin-3-glucoside (Yawadio *et al.,* 2006). Ichikawa *et al* (2001), Ryu *et al.* (1998) who have demonstrated that the structure-biological activity relationship of phenolic compounds, hence, the present work focused on the structure elucidation of phenolic compounds from pigmented rice and anti-enzymatic activity. Many works were study on pigmented rice in order to elucidate both their phenolics profile and related antioxidant activities. There is a significant positive correlation between the black rice contents in the extract and their antioxidative potency.

The health benefits of flavonoids are usually linked to two properties; (i) inhibition of certain enzymes and (ii) antioxidant activity (Cotlelle, 2001). There were researches about the antioxidative and radical scavenging properties of black rice bran extract, which include the properties to provide prevention of various disease associated with oxidative stress such as cancer (Chen *et al.*, 2006) and cardiovascular disease (Jerzy *et al.,* 2003). Xia *et al* (2003) showed that supplementation of black rice bran compared with white rice, significantly reduced atherosclerotic plague formation induced by feeding high dietary cholesterol to rabbits. This effect related to higher phenolic compounds, vitamin E, selenium, iron and zinc concentrations in black rice (Ling *et al.,* 2002). Black rice comprises a higher content of phenolic compounds than other grains, and it is expected to be utilized as an antioxidant in functional food.

The contents of the functional components of pigmented rice were different according to the cultivation conditions and their total production per unit area depended on the brown rice yield. There were reported that the content of functional components of pigmented rice were significantly increased according to the level of N-fertilizer and normal planting conditions showed significantly higher effects than early or late planting and the contents were different according to planting region (Jung *et al.*, 2003). Among red, purple and black rice, the level of the anthocyanin varied greatly. Rice with black bran was found to have the highest level of the anthocyanin (Le, 2005). Chae *et al.* (2004) study in change of anthocyanin pigment and antioxidant activity as affected by ripening temperature (17, 21, 24 and 27$^{o}$C) in rice. The result showed that cyaniding-3-gluciside content per pot were significantly higher at 24$^{o}$C. Antioxidant activity were also significantly higher at 21-24$^{o}$C.

## 2.2 PHENOLOGICAL DEVELOPMENT AND GROWTH OF RICE

Phenological development relates to the physiological age of plant and its morphological appearance (Penning de Vries and van Larr, 1982). Growth refers to the increasing of weight, volume, length and area of some part or all of the plant (Ritchie and NeSmith, 1991). The total amount of growth for a given time interval depends on photosynthesis, whereas partitioning of assimilates to plant organs which control by plant development stage. Development rate is not constant. It is fluctuates as a function of air temperature and photoperiod. These factors are especially important during the vegetative phase (Wopereis *et al*., 2009).

The development of rice may be divided into three phases (De Datta, 1981).

1. The vegetative phase refers to a period from germination to panicle initiation. In this stage is characterized by active tillering, gradual increase in plant height and leaf emergence at a regular intervals. Tillering stage may start when the main clum develop the 5th or 6th leaf. Active tillering stage refer to a stage when the increasing in tiller number per unit of time is high. The maximum tillering stage follows active tillering. It is a stage which tiller number per plant is maximum. It can be occure before or after the panicle initiation.
2. The reproductive phase refers to a period from panicle initiation to heading. In this stage is characterized by clum elongation, declining of tiller number, emergence of flag leaf, booting, heading and flowering. Panicle

initiation stage begins when the primordium of the panicle has differentiated and become visible, the the panicle continues to develop. During the panicle development, the spikelets become distinguishable and the panicle extends upward inside the flag leaf sheath, when the flag leaf sheath is swell called booting stage. Heading stage is the emergence of the panicle out of the flag leaf sheath. Flowering begins with panicle exertion, or on the following day.

3. The ripening or maturity phase refers to a period from flowering to maturity. In this stage is characterized by leaf senescence and grain development. Ripening may be subdivided into three stage i) milky stage, the content of the grain is a white liquid. ii) dough stage, the milky portion of grain turn into a soft and hard dough. iii) mature stage, the grain color begins to change from green to yellow. The maturity stage characterized by 90-100% of filled spikilets have turned yellow. The flag leaf is start senescence.

Counce *et al.* (2000) proposed that rice development stage divided into three main phases : seedling, vegetative and reproductive. Seedling development consists of four growth stages: unimbibed seed (S0), radicle and coleoptile emergence from the seed (S1, S2), and prophyll emergence from the coleoptiles. Vegetative development consists of stages V1, V2 . . . V*N*; *N* being equal to the final number of leaves with collars on the main stem. Reproductive development consists of 10 growth stages based on discrete morphological criteria: panicle initiation (R0), panicle differentiation (R1), flag leaf collar formation (R2), panicle exertion (R3), anthesis (R4), grain length and width expansion (R5), grain depth expansion (R6), grain dry down (R7), single grain maturity (R8), and complete panicle maturity (R9).

## 2.3 LEAF DEVELOPMENT OF RICE

Leaf appearance is one of the important aspects of development in rice (Gao *et al*., 1992; Ellis *et al*., 1993) which can be used to determine the response of development to temperature (Ritchie and NeSmith, 1991). Flowering time of cereal crop is can be predicted on the basis of leaf appearance, panicle emergence immediately follows the fully expanded of flag leaf.

Temperature is the principle environmental determinant of crop leaf appearance (Ritchie, 1993). The study in controlled-environment experiments grown rice under five constant temperature (22, 24, 26, 28 and 32$^{o}$C) and four diurnally-fluctuating temperatures ($T_D/T_N$:26/22, 30/22, 22/26 and 22/30 °C). The leaf appearance on the main stem was measured. The result indicated that the leaf development at diurnally fluctuating temperatures was accurately predicted on the basis of the relationships established from the constant temperatures (Yin and Kropff, 1995). There are no specific effects of day temperature and night temperature on leaf development in rice.

Leaf number is linearly related to accumulated thermal units from seedling emergence. Heat units, expressed in growing degree days (GDD), are frequently used to describe the timing of biological processes. Particularly in areas of crop phenology and development. The concept of heat units has vastly improved description and prediction of phenological events.

The basis equation used is

$$GDD = \frac{(T\max + T\min)}{2} - Tbase$$

Where

$T_{max}$ is the daily maximum air temperature. $T_{max}$ is set equal to 30°C when greater than upper threshold temperatures. The upper threshold temperature equal to 30°C for rice.

$T_{min}$ is the daily minimum air temperature. $T_{min}$ is set equal to $T_{base}$ if less than $T_{base}$.

$T_{base}$ is the temperature which is temperature below which plant growth is zero. The base temperature used for rice was 10°C.

## 2.4 FACTORS EFFECTING PHENOLOGICAL DEVELOPMENT AND GROWTH

### Temperature

The rates of most biological processes are affected markedly by temperature. Growth and development of whole organism show a temperature response which results from the integrated effect of temperature on the many individual physiological processes involves (Russelle *et al*., 1984). Plant development was not as closely related to time as to accumulated temperature (Neild and Seeley, 1977). Many studies are reported that the usefulness of growing degree day or heat units for predicting crop growth and development, classifying crop species, hybrids and varieties, or evaluating climates for specific crop management combinations (Andersen and Andersen, 1981; Crane *et a*l., 1977; Cross and Zuber, 1972; Fairey, 1983; Neild and Seeley, 1977; Shaw, 1975; Tscheschke and Gilley, 1979). Most proposed that accumulated temperature show significantly greater correlation with plant growth and development than does accumulated times, although differences in the relationship among accumulated temperature are slight (Coelho and Dale, 1980; Crane *et al*., 1977; Cross and Zuber, 1972; Gilmore and Rogers, 1958; Kiniry and Keener, 1982; Tollenaar *et a*l., 1979).

### Photoperiod

The photoperiod effects growth and development of many field crops (Gardner and Allard, 1920). There are reports that photoperiod effects on the initiation of floral buds, flowering time and other traits (Thomas and Vince-Prue, 1997). Many species and genotypes of crops are classified as short-day plant (SDP), long-day plant (LDP) and day-neutral plant on basis photoperiod requirements (Gardner and Allard, 1920). In rice, the time to flowering is strongly effected by photoperiod. In general, a short photoperiod accelerations and long photoperiod delays flowering (Vergara and Chang, 1985). The duration from panicle initiation to flowering was positively correlated with the photoperiod experiences after panicle initiation (Yin and Kropff, 1997). Yin *et al*. (1997) estimated this photoperiod sensitive duration to be several days. Thus, the stage up to flowering may be divided into four phases: BVP, photoperiod inductive for panicle initiation, photoperiod sensitive and insensitive phases for panicle development (Nakagawa and Horrie, 1997). If panicle initiation is not considered, the duration from sowing to flowering may be divided into three stages: the BVP, the photoperiod-sensitive phase (PSP) and postphotoperiod-sensitive phase (PPP) (Yin *et al*., 1997) Nakagawa and Horie (1995) showed further improvement in estimation of flowering time when the vegetative (up to panicle initiation) and reproductive (from panicle initiation to flowering) stages were separated and the vegetative stage was divided into two phases: insensitive to photoperiod and sensitive to photoperiod. The effect of photoperiod does not end however at panicle initiation and flowering will be delayed if plants are grown under a longer photoperiod for some time after panicle initiation (Collinson *et al.*, 1992)

## 2.5 STELLA

STELLA is a program designed to assist users in creating their own simulations using system dynamics. This program uses an iconographic interface to facilitate construction of dynamic system models.

The key features of STELLA consist of the following tools

1. Stocks, which are the state variables for accumulations. They collect whatever flows into and out of them.
2. Flows, which are the exchange variables and control the rate of incoming and outgoing materials from state variables.
3. Converters, which are the auxiliary variables. These variable can be represented by constant values or by values depending on other variables, curves or functions of various categories.
4. Connectors, which are to connect among modeling features variables and elements. It show the direction of relationship in a system.

STELLA offers a practical way to dynamically visualize and communicate how complex systems and ideas really work (Isee System, 2006). STELLA has been widely used in biological, ecological, environmental and agricultural science.

(Hannon and Ruth 1994; Peterson and Richmond, 1996; Costanza *et al*., 2002; Aossine and El Jai, 2002; Ouyang *et al*., 2007).

Ouyang (2007) used STELLA to develop a system dynamic model for uptake and translocation of contaminants from a soil–plant ecosystem (UTCSP). The structure of UTCSP consists of time-dependent simultaneous upward transport, accumulation, and transpiration of water and contaminants in a soil–plant–atmosphere ecosystem, which was driven by water potential gradients among soils, roots, stems, leaves and atmosphere. The UTCSP model was modified to simulate the uptake and transport of TNT (2,4,6-trinitrotoluene) by a poplar tree, which was divided into three sectors representing roots, stems and leaves, respectively. Each sector was further divided into two compartments, one for xylem and the other for phloem (Ouyang *et al*., 2007).

## 2.6 CROP GROWTH MODEL

Crop growth is a very complex phenomenon and product of a series of complicated interactions of soil, plant and weather. Dynamic crop growth simulation is a relatively recent technique that facilitates quantitative understanding of the effect of these factors, and agronomic management factors on crop growth and productivity. These model are quantitative description of the mechanisms and processes that result in growth of the crop. The process could be crop physiological, meteorological, physical and chemical processes. Such a modeling assumes that the rate of change of system can be closely approximated by considering the rate of processes to be constant during short time periods. This is based on state variable approach in which current states (for example, weight of plant parts, evapotranspiration, leaf area index) are updated after every short interval (usually one day) considering the previous state and the rate which is influenced by interval crop properties and environment. This is repeated till the crop is mature. Models that deal with crop growth simulation can be distinguished into two categories: Descriptive and Explanatory.

Descriptive models define the behavior of a system in simple in simple manner. These models show the existence of relations between the elements of a system but reflect very little, if at all, of the mechanisms involved underlying the behavior of that system.

Explanatory models consist of quantitative descriptions of the mechanisms and processes involved that are responsible for the behavior of the system. For an explanatory model the system is analyzed and its processes and mechanisms are quantified separately. The model is the built by integrating these descriptions for the entire system. Explanatory models are means by which knowledge about systems and their performances is made portable and accessible to users whose livelihood and welfare depend on the systems performance. Models are extremely useful because the critical environment problems not disciplinary ones. Their solutions demand a multi-disciplinary approach linking basic and applied sciences.

The behavior of a crop growth model can be explained by the basic physiological, physical and chemical processes and the effect of environment factors on them.

Crop simulation models can dynamically describe the biophysical and physiological processes of growth, development and yield and provide a quantitative tool for predicting the productivity level of crop in relation to genotype, environment and management (Bouman *et al.*, 1996; Jamieson *et al.*, 1998; Van Ittersum *et al.*, 2003).

Crop growth simulation models are recognized as valuable tools in agricultural research. It can help to compare experimental research findings across sites, extrapolate experimental field data to wider environments, develop management recommendations and decision-support systems, explore effects of climate change, and make yield predictions. (Bouman *et al.*, 1996; Jones *et al.*, 2003). There are several growth simulation models for predicting rice crop performance such as CERES-Rice (Singh *et al.*, 1993), SIMRIW (Horie *et al.*, 1992), ORYZA2000 (Bouman *et al.*, 2001), RiceGrow (Tang *et al.*, 2009).

CERES-Rice (Singh *et al.*, 1993) is a generic and dynamic simulation model that is part of DSSAT system (Godwin and Jones, 1991; Singh, 1994; Godwin and Singh, 1998; Ritchie *et al.*, 1998; Jones *et al.*, 2003). It contains a detailed description of crop growth under optimal, nitrogen-limited, and water-limited conditions. CERES-Rice was calibrated and evaluated using experimental data from more than one site or from more than one season only once. Model evaluations are generally limited to graphical comparison of simulated and measured crop growth variables with little to no quantitative goodness-of-fit parameters given.

SIMRIW (Horie *et al*., 1992) is a simplified process model for predicting crop growth and yield from daily weather. This model integrates the processes of ontogenetic development, biomass accumulation and yield formation through their rational simplification.

ORYZA2000 (Bouman *et al*., 2001) is a model was designed to simulates growth and development of lowland rice in situations of potential production, water limitations, and nitrogen limitations. It is assumed that, in all these production situation, the crop is well protected against weeds, pests and diseases.

FARMSIM (Schaber, 1996) is a dynamic model for the simulation of yields, nutrient cycling and resource flows on Philippine small-scale farming systems. It is a whole farm model to quantify flow of nutrient between the different farming enterprise. This model is combined the ORYZA_0 rice simulation model with a fish pond model and model of pig, chicken and buffalo by using STELLA modeling package.

RiceGrow (Tang *et al.,* 2009) is a simulation model for predicting growth, development and productivity of rice under changing environment condition. This model included seven sub-model for simulating phenology, morphology and organ formation, photosynthesis and biomass production, dry matter partitioning, yield and quality formation, water relations and nutrient balance. It can be used to rice growth and development with varied genotypes, environment conditions and management practice.

For application, when appropriate parameters and functions are available, the model may used to predict potential productivity of different crops under varying conditions and at different location (Penning and van Laar, 1982). To achieve the productions as predicted by the model in the real situation for validation purpose, growing conditions should be optimal in terms of supply with water and plant nutrients, weed should not seriously interfere with crop production and the crop should be free of pests and diseases. Crop growth models are powerful tools to predict crop yield changes caused by these changes and other environmental inputs, i.e. water and nitrogen applications. Crop yield depends on interaction between soil, water, plant, and atmosphere as a continuum system. Simulation of plant-growth stages and consequently forecasting the crop yield permits better planning and more efficient management of crop production.

## 2.7 APPLICATION OF CROP SIMULATION MODEL

Environmental characteristics: Crop models together with GIS can greatly facilitate demarcation of homologous zones at mega-, macro-, meso- as well as micro level depending upon the availability of data and objectives. These tools have been used to determine potential and attainable yield for given level inputs for various crops. Potential yield of cultivars varies with season/year and location. Estimates of such yields for different varieties can establish a reference point for site quality and remove the confounding effects associated with large climatic variation.

Optimizing crop management: Once potential yields have been quantified, these can be converted to attainable yields to determine magnitudes of yield gap. Crop growth modeling can be used to in matching agro-technology with the farmers resources and analyzing the precise reasons for yield gap. Recent studies have shown that simulation models can help fine tune the N fertilizer application recommendations in irrigated rice (Berge *et al*., 1996). Studies done in China, India, Indonesia and Philippines showed that simulation model recommendations helped in increasing the fertilizer efficiency by 15-20%.

Pest and disease management: At a regional level, GIS, requisite environmental data coupled with epidemic simulation models further provide geographic delineation of disease and insect pest risk zones. These zones can also help us in making strategic decisions on deployment strategies for varieties and to determine how long host plant resistance would be expected to last. Historical climate data from sites have been shown to be useful for characterizing the conduciveness of a site to specific diseases. Attempts are also being made to integrate disease predictive system with online weather and weather-interpolation systems.

Yield loss studies have conventionally quantified the relations between nitrogen application rate, disease severity, season and grain yield. This has resulted in a quantitative understanding of the host-pathogen-environment interactions and in disease management recommendations. However, validity of such recommendations is limited, as strongly influenced by disease onset, disease spreading rate, farm management practices, environmental conditions and their interactions. Physiologically based simulation models can be applied to understand the damage mechanisms and analyze their effects on crop growth and yield of rice.

Impact of climate change: Crop models are being used to estimate the impact of increased carbon dioxide and temperature on crop production (Matthews *et al*., 1995). It was assumed that the trends in potential yields would also be shown in actual yield. These models can utilize the input from Global Circulation Models (GCM) to quantify the impact of climate change.

Yield forecasting: Reasonably precise estimates of acreage and yield before the actual harvest are of immense value in policy planning. The relatively small cost and speed of assessment makes crop growth simulation models promising for areas where significant daily weather data are readily available. In this approach, the model is run using actual weather data during the cropping season for the geographical region on interest. Weather data for typical years are used to continue simulations until harvest. Horie *et al* (1992) showed an example where crop models, regional weather databases and historical yield data in used to forecast rice yield for different regions of Japan. There is an urgent need to develop such models for Indian situation.

Optimal sowing dates for hybrid seed production: a major constraint to utilizing hybrid seed technology is the need to by fresh seed every planting season and the high cost of seed production. This limited seed production is largely due to poor out-crossing and asynchronous flowering of male and female parents. Environmental factors such as temperature, humidity and wind speed as time of the pollination and fertilization plan a great role in regulating outcrossing percentage. To synchronize these at several locations to determine the optimal planting dates, crop simulation modeling is a more efficient tool in making decisions about the planting calendar of parents in different environments (Xu, 1995).

Increased efficiency of Multi-environment evaluation: Development and release of a variety is a complex process that may extend over period of 10-15 years. Once the breeding lines have become homozygous, they are bulked and then tested in observational, replication and multilocation yield trials. These multi-site trials are expensive and need several crop seasons/locations to understand genotype by environment (GxE) interactions.

Since the systems approach integrates different components of agroecosystems, it can play a great role in increasing the efficiency of plant breeding process, in particular multienvironment testing of genotypes. Crop models together with GIS can facilitate biological characterization of the physical environment domains for which improved varieties are to be developed. Alternatively, the same methodology can be used to determine the adaptation domains of genotypes. A modeling approach can also provide estimated for yield probability in target environments based on the understanding of GxE interactions. Such studies can help in reducing the number of sites/season required for field evaluation and thus increase the efficiency of the whole process of variety development.

A very simple role for crop modeling would be the provision of an index of site quality for use in traditional GxE analysis. This could be achieved by simulating performance of number of check varieties over a wide range of weather conditions at each site. Regression of observed test variety lines on the simulated index would give an idea of stability. Regression of the same check variety yield on the simulated index would give an idea of the effect of specific weather conditions.

Model are means to capture, condense and organize knowledge. A well tested model can be a very effective scientific tool for tailor-made introduction of new production technologies, working out alternative crop production strategies, provide answer to the ‘WHAT IF’ questions raised by technology adopters, to identify problems and prioritize research, to optimize precious resources by reducing the number of field experiment, to assist in policy and strategy applications, for environmental characterization and agroecological zoning, for seeking new domains and as a very effective teaching aid.

A number of opportunities are now available for the use of crop simulation models for quantifying the effects of various factors including weather on agriculture. The key areas are biophysical characterization of agro-environments, evaluating impact of climate change, optimizing crop, pest and disease management, and increasing the efficiency of multi-environment testing, forecasting crop yield, etc. It is now possible to explain with simulation models the effect of environmental variability on crop growth and yield. The response of standard cultivars to environment can be predicted with confidence. In future, the systems approach, with its well developed analytical framework, data bases, and powerful simulation models, will be handy to provide answers to many to the current agricultural issues in made to develop models that can integrate the effect of all important factors operating in the field environment, for instance, weather, edaphic conditions, management, incidence and effect of pests and socio-economics.