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Review on Effect of Low Temperature on Productivity of Rice in Ethiopia

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ABSTRACT

Rice (Oryza sativa L.) is the main source of staple food for human consumption. Low temperature is the major problem for the agricultural production and it affects rice production globally. Rice is a cold-sensitive plant that has its origin in tropical or subtropical areas and cold damage can cause serious yield losses. Low temperature affects the rice cultivation mainly in two stages of development i.e. seedling and booting. In both of them, cold temperature has harmful effects on crop productivity. Low temperature during the reproductive stage in rice causes degeneration of spikelets, incomplete panicle exsertion and increases spikelet sterility thus reducing grain yield. The most sensitive stage to low temperature is the booting stage. The percentage of fertile spikelet has been used as effective parameters of cold tolerance of rice at booting stage. Low temperature at booting stage causes anther injury, degeneration of young microspores, resulting in high spikelet sterility and reduced rice yield. Understanding effect of low temperature in rice productivity became an important step.

Keywords: *Rice, Low Temperature, production, Stress,*

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important food crops in the world. It is a staple food crop for more than half of the world's human population. Rice grain contains 75 to 80% starch, 12% water and 7% protein (Oko *et al*., 2012) minerals like calcium, magnesium and phosphorus are present along with some traces of iron, copper, zinc and manganese. In addition, rice is a good source of niacin, thiamine and riboflavin (Yousaf, 1992; Oko *et al*., 2012).Rice belongs to *Gramineae* or grass family. The genus, to which it belongs, *Oryza*, contains more than 20 species, only two of which namely Oryza *sativa* and *Oryza glaberrima* cultivated in world wide. Rice is a monocotyledonous angiosperm. It is diploid with 24 chromosomes which can be distinguished individually using cytogenetic techniques (Fukui and Lijima, 1991).

The physiological metabolisms of rice are negatively affected by various abiotic stresses by altering its grain yield. Cold stress is one of the abiotic stresses which are common problem of rice cultivation. It causes various injuries to rice seedlings in low-temperature and high-altitude areas and is therefore an important factor affecting rice production in such areas (Xiao *et al*., 2015). Rice is a cold-sensitive plant that has its origin in tropical or subtropical areas, and cold damage can cause serious yield losses. Understanding effect of cold stress in rice production became an important step. Therefore, the objective of the paper was to understand effect of low temperature on productivity of rice in Ethiopia.

LITERATURE REVIEW

Rice Production in Ethiopia

Rice was introduced in Ethiopia in the 1970s and has since been cultivated in small pockets of the country. Rice has a great potential to contribute to food self-sufficiency and food security in Ethiopia. In the country, four rice ecosystems are identified and these are: upland rice, hydro orphic (rain fed lowland) rice, irrigated lowland ecosystem, paddy rice (with or without irrigation).

Rice is one of the main sources of food in the world where the increased demand for rice is expected to enhance production in many parts of Asia, Africa and Latin America. Most of the world's rice is cultivated and consumed in Asia which constitutes more than half of the global population (Chakravarthi and Naravaneni, 2006).In developing countries, rice accounts for 715 Kcal per capita/day and provides 27% of global human per capita energy, 20% of per capita protein, and 3% dietary fat (FAO, 2002).

World rice production increased at a rate of 2.3to2.5% per year during 1970s and 1980s, but this rate of growth was only 1.5% per year during the 1990s. The yield growth rate for rice has further declined during the first decade of 21st century. However, the populations in the major rice-consuming countries continue to grow at a rate of more than 1.5% per year. The average rice productivity in Ethiopia is estimated at 2.8 t ha^{-1} (MoA, 2010), which is much lower than the World's average of 4.4 t ha^{-1} (FAO, 2012).

Despite the fact that, considering its important rice has been recognized by the government as "the new millennium crop of Ethiopia" to attain food security, but lack of improved varieties, lack of recommended crop management, lack of pre and postharvest management, biotic and abiotic stresses limit the production and productivities of the crop in the country (EIAR/ FRG II, 2011 and MoA, 2010). Poor access to improved varieties is ranked first as priority rice production inputs constraint (EIAR/ FRG II, 2011). Therefore, development of high yielding rice genotypes with desirable agronomic traits for different ecosystem is essential to meet its future demand (Mulugeta et al., 2012).

Major Abiotic Stresses for Rice productivity

Rice is one of the major food crops of the world and almost half of the worlds' population consumes it every day. Due to ever the increasing population, the demand on rice production has also increased. However, its yield is affected due to various biotic and abiotic stresses. Abiotic stresses affecting rice production include drought, salinity, high and low temperatures, UV radiations, etc. Rice plants tend to respond to stresses by activating signaling pathways. Different genes are up- and down-regulated in response to abiotic stress which initiates or inhibits various signaling processes and make the plant tolerate to stress conditions. Cold stress is one of the abiotic stresses which are common problem of rice cultivation. It causes various injuries to rice seedlings in low-temperature and high-altitude areas and is therefore an important factor affecting rice production in such areas (Xiao et al., 2015).

Rice is a cold-sensitive plant that has its origin in tropical or subtropical areas, and cold damage can cause serious yield losses. Low temperature effects the rice cultivation mainly in two stages of development i.e. seedling and booting. In both of them, cold temperature has harmful effects on crop productivity, as in the first case the number of established plants is affected and in the booting stage pollen sterility can be induced by cold, decreasing the final number of grains. Apart from the two critical stages, low temperature stress can also be manifested at different growth stages such as germination, seedling, vegetative, reproductive, and grain maturity (Andaya and Mackill, 2003a).

Cold stress has many negative impacts on the productivity of rice cultivars like it reduces growth of seedling, weakens photosynthetic ability, reduces plant height, delays days to heading, reduces spikelet fertility, and cause poor grain quality (Suh et al., 2010). It may also cause various seedling injuries, delayed heading and yield reduction due to spikelet sterility. The seedlings treated under low temperature suffer severe stunting, leaf yellowing and also appear necrotic as brown spots on the stem (Andaya and Mackill, 2003b).

Therefore, cold tolerance at the early seedling stage is of particular importance, especially to direct seeded rice cultivation. Low temperature tolerance at the seedling stage has also been evaluated by determining survival percentages, as susceptible seedlings have problems in maintaining normal metabolic rates under cold and ultimately die (Morsy et al., 2007). The most sensitive stage to low temperature is the booting stage. The percentage of fertile spikelet has been used as effective parameters of cold tolerance of rice at booting stage.

Low temperature at booting stage causes anther injury, degeneration of young microspores, resulting in high spikelet sterility and reduced rice yield. Cold temperature during the reproductive phase leads to seed sterility, which reduces yield and the grain quality of rice. The fertilization stage, ranging from pollen maturation to the completion of fertilization, is sensitive to unsuitable temperature. In cold temperature areas, improving cold tolerance at the fertilization stage (CTF) is an important objective of rice breeding program. Low temperature at the booting stage has also been reported to cause degeneration of young microspores, and hypertrophy and dissolution of tapetal cells, interrupting or decreasing the supply of nutrients from the anther walls to the pollens (Satake,1989). Crops are exposed to varied environmental conditions during their life cycle. Cold stress is a major environmental factor limiting the growth, productivity, and geographical distribution of crops. It can be classified as chilling (0-15°C) and freezing (<0 °C) stress.

As rice is originated in tropical and subtropical regions, it is more sensitive to cold stress than other cereal crops such as wheat (Triticum aestivum L.) and barley (Hordeum vulgare L.). Therefore, in this review we focus on the low temperature stress mainly in the reproductive stage of rice that can adversely affect grain quality or cause yield reductions.

Effects of Cold Stress in Rice Productivity

Even though cold temperature affects rice growth from seed germination to seed maturity, cold temperature at reproductive phase decrease seed set. Two stages of the reproductive phase in rice are known to be the most sensitive to cold temperature: booting stage and fertilization stage. At booting stage, ranging from pre-meiotic mother cells to microspores and pollen maturation, cold temperature can disrupt mitosis I and II, which prevents rice microspores from maturing into normal tricellular pollen grains (Satake, 1989).

The fertilization stage begins just after pollen maturation and the complete fertilization stage consists of anther dehiscence, pollen germination, pollen tube elongation and fertilization. Due to the negative effects of low temperature on rice growth, cold tolerance is an important feature for both, temperate and high altitude, regions.

Ghadirnezhad and Fallah (2014) reported that low temperature had significant effect on all characters, such as number of panicles, length of panicle, and number of full, empty, and total grains; as a result, yield was significantly reduced. Further, they discovered the interaction between temperature and varieties showed that most tolerant variety in relation to temperature stress had least percentage yield decrease (19%) was shirudi variety and the most sensitive one with most percentage of yield decrease (29%) was local tarom variety. Xu et al. (2008) evaluated cold tolerances of F2 plants on the basis of spikelet fertility of main panicles at seed ripening stage, and those of F lines were evaluated as mean spikelet fertility of the main panicles from 15 to 20 plants in each line. They reported severe reduction of spikelet fertility in susceptible lines. Many species of tropical or subtropical origin are injured or killed by nonfreezing low temperatures, and exhibit various symptoms of chilling injury such as chlorosis, necrosis, or growth retardation. In contrast, chilling-tolerant species are able to grow at such low temperatures (Sanghera et al., 2011). According to Ye et al. (2009) yield losses due to cold temperature are a result of incomplete pollen formation and subsequent floret sterility.

In Australia, rice farmers suffered losses ranging from 0.5 to 2.5 t/ha in 75% of the years due to low temperature during the reproductive stage. During the grain filling stage, chilling temperature may cause delayed and incomplete grain maturation.

Transferring cold tolerance from different sources to locally adapted cultivars requires the presence of the selective agent, in this case the low temperature. However, its abiotic nature makes it unpredictable under field conditions in terms of its intensity, duration, and timing that limit field selection for cold tolerance in rice (da Cruz and Milach, 2000).

Singh et al. (2005) identified overseas rice varieties that were cold tolerant under local weather conditions and by using those genotypes as parent material, developed cold tolerance varieties of rice. Kim et al. (2011) identified two SNPs (single nucleotide polymorphisms) in OsGSTZ2 and suggested that cold sensitivity in rice is strongly correlated with a naturally occurring Ile99Val mutation in the multifunctional glutathione transferase isoenzyme GSTZ2.

Perveen et al. (2013) observed the effect of low temperature stress on two rice varieties (Basmati-385 and Shaheen). They found the concentrations of photosynthetic pigments were negatively affected by low temperature stress in both varieties. In Basmati-385, chlorophyll 'a'content had a maximum value (5.731 µg/g) at -2 °C and the lowest value (4.64 µg/g) was seen at -4 °C. Chlorophyll 'b' content was also decreased under low temperature stress in Basmati-385, showing the lowest value (4.1 µg/g) at 0°C. Suzuki et al. (2008) reported that the effects of cold stress at the reproductive stage of plants delay heading and result in pollen sterility, which is thought to be one of the key factors responsible for the reduction in grain yield of crops.

Conclusion

Rice (Oryza sativa L.) is one of the most important food crops in the world. It is a staple food crop for more than half of the world's human population. Low temperature is a common problem in rice cultivation in temperate zones and high-elevation environments in tropical and subtropical areas, as well as in irrigated areas which rely on the use of cold water. Cold stress has many negative impacts on the productivity of rice cultivars like it reduces growth of seedling, weakens photosynthetic ability, reduces plant height, delays days to heading, reduces spikelet fertility, and cause poor grain quality.

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