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Seed germination and seedling growth of rice varieties as affected by flooding stress

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ABSTRACT

Submergence tolerance is an important character to be considered when flash flood damages rice. Tolerant genotypes can withstand submergence for 1–2 weeks based on their tolerance level. Hence with a view to study the effect of submergence on germination and seedling attributes, eight cultivated varieties were subjected to submergence tolerance at five levels of flooding *viz*., 1 cm, 2 cm, 3 cm, 4 cm and 5 cm flooding levels. CR 1009 sub 1, a submergence tolerant variety was used as check. With increase in submergence levels, greater reduction was observed for all the parameters. Survival % and seedling length were found to be decreased under flooded conditions, but to a much lower extent in the tolerant genotype. Flooding decreased shoot, root and total dry matter production in all the varieties with more reduction in higher flooding (5 cm) rather than lower flooding (1cm) levels.

Key words : Rice, Flooding, Germination, Seedling characters.

INTRODUCTION

Abiotic stresses are one of the major causes of crop failure, decreasing average yield in most of the crops by more than 50% (Mahajan and Tuteja, 2005). Abiotic stresses adversely affect the agricultural productivity (Bartles and Sunkar, 2005) by altering their growth and development. Waterlogging and flooding are common in rain-fed ecosystems, especially in soils with poor drainage. As a consequence of disturbed physiological functioning, vegetative and reproductive growth of plants is negatively affected by flooding (Gibbs and Greenway, 2003) and hence flooding and waterlogging may lead to reduction in yield (Dennis *et al*., 2000).

Flooding is defined as water supplied in excess to an area. Flooding occurs when soil has been saturated with water or a situation where water enters the soil faster than it can drain away under gravity (Vartepetian, 2003). Excess of water in the soil (flooding) displaces air from non capillary pore spaces thereby producing oxygen deficiency resulting in decreased transportation, translocation and the production of adventitious roots (Boru and Boersma, 2003). Flooding leads to poor development of roots and shoots (Onuegbu, 1997). Flooding is an environmental stress that affects crop growth and productivity. It has become a major problem in many countries of the world. It may aggravate further due to global warming in future. Bange *et al*. (2004) reported that flooding can result in yield reduction of up to 10%.

Seed germination, seedling, vegetative and reproductive stages are adversely affected by abiotic stresses like saline and flooding stresses. Germination and seedling growth are very important for early establishment of plants under these stress conditions. Hence selection of crop varieties for rapid and uniform germination under such stress conditions can significantly contribute towards earlier establishment.

Rice (*Oryza sativa* L.) is the primary food for half the people in the world which provides more calories than any other single food (Maksudul Haque *et al*., 2015). Submergence of rice (*Oryza sativa*) by flash flooding is a major constraint in many rice producing countries in Asia. During germination of rice seeds in paddy fields (either waterlogged or submerged), plants are exposed to hypoxia or anoxia. Genotypic variation in rice responses to direct seeding into anoxic soils has been reported by Yamauchi *et al*. (1993), and many other researchers. Rice cultivars also vary in their capacity to tolerate complete submergence (Pierdomenico Perata and Laurentius ACJ Voesenek, 2007). Traits associated with coleoptile elongation of pregerminated seeds under anoxia has been investigated by Setter *et al*. (1994). In this study, attempts were made to elucidate tolerance of rice varieties to flooding during germination and early seedling growth using a set of varieties along with CR 1009 sub 1 as check, a submergence tolerant variety.

MATERIALS AND METHODS

Dry seeds of IR 64, ADT 49, ADT 39, CO 43, BPT, ADT 43, ADT 36 along with CR 1009 sub 1 as check were sown in paper cups filled with acid washed sand and flooded with five levels of flooding *viz*., 1cm, 2cm, 3cm, 4cm, and

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5cm levels of water. Seedling survival and shoot and root growth were assessed by taking their length and dry weights 15 days after sowing. The experiment was conducted under laboratory conditions in CRD with three replications and with temperature maintained at about 26 °C.

Survival % : The number of seedlings emerging from the water surface was recorded and survival was calculated based on the number of seedlings that emerged from floodwater and expressed as the percentage of surviving seedlings to the number of seeds used. Germinated seeds were those with emerging radicle or coleoptile visible to the naked eye.

Seedling length: Lengths of the longest shoot and root were measured in seedlings grown under different flood levels and all the measurements were made 15 days after sowing. Shoot and root length were measured on a glass plate and expressed in cm. Shoots included all aerial parts and roots included all below-ground material excluding seeds.

Dry matter production: The shoots and root were separated, oven dried at 60^{0}c for 24 hours and dry weights were immediately taken. Reduction in dry weight % (RDW %) was worked out by using the following formula keeping CR 1009 sub 1 as check.

RDW % =

$$100 \times (1\text{-Dry weight}_{\text{salt stress}} / \text{Dry weight}_{\text{control}}).$$

RESULTS AND DISCUSSION

Survival % : Among the eight varieties studied, ADT 39 recorded higher survival % (90.6) followed by CR1009 sub 1 (88.4) whereas ADT 36 recorded only 78.2% survival in 1 cm flooding level (Fig 1). Whereas, in all other flooding levels from 2 cm to 5 cm CR1009 sub 1 recorded higher survival% (88.4-76.6) followed by CO 43 (86.2-50.2) (Fig 2- Fig 5). ADT 36 recorded lowest survival % in all flooding levels ranging from 78.2 % at 1 cm flooding to 24.0 % at 5 cm flooding level. In general, it was found that with increase in flooding level, survival % was found to decrease drastically.

Survival of rice seedlings decreased under flooded conditions, but to a much lower extent in the tolerant genotypes. Under flooding, growth of both shoot and root started earlier in tolerant genotypes and proceeded faster than growth in intolerant ones. Probabably, they might have the ability to use the stored starch reserves through higher amylase activity and higher rates of ethylene production and lower peroxidase activity. (Ismail *et al*., 2009). It has been reported that tolerance of flooding during germination is a complex process involving numerous mechanisms. But it is clearly not associated with tolerance of complete submergence during the vegetative stage, as demonstrated by the sensitivity of FR13A, a landrace most tolerant of complete inundation during the vegetative stage (Ella *et al*., 2003; Jackson and Ram, 2003).

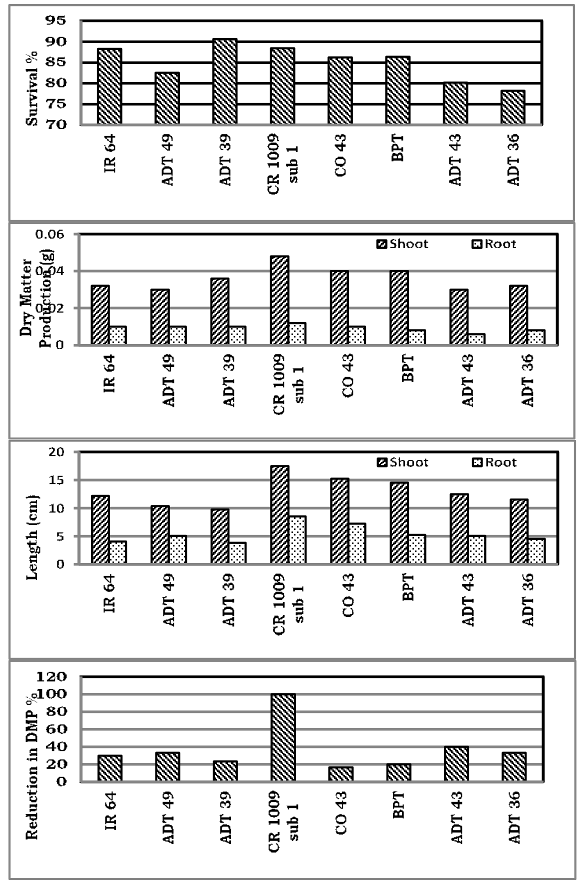

Fig 1: Effect of flooding stress (1 cm) on germination and seedling attributes

Seedling length : Among the varieties studied, CR1009 sub 1 produced lengthier seedling in all the flooding levels. It recorded highest shoot length ranging from 17.51 cm to 8.26 cm from 1 cm flooding to 5 cm flooding (Fig 1 - Fig 5). It was followed by CO 43 which produced 15.2 cm at 1 cm flooding and 7.00 cm at 5 cm flooding. Similarly, CR 1009 sub 1 registered higher root length of 8.56 cm at 1 cm flooding and 7.24 cm root length at 5 cm flooding followed by CO 43 which recorded next best values in all the flooding levels. In general, reduction in seeding length was more in higher flooding (5 cm) when compared to lower flooding (1 cm) levels. Gibbs and Gainers (2003) reported that water logging of the soil depresses shoot growth, causes injury and oxygen depletion in plants. Ellis (1998) also reported reduced plant height as a result of lack of oxygen which causes critical functions of the plant to be impaired.

In plants, roots are first organs which encounter any stress and it is likely that roots may be able to sense and respond to such stress conditions. Root length at seedling stage provides a fair estimate about the root growth in field (Ali *et al*., 2011; Rajendran *et al*., 2011). Differential responses of shoot and root growth were also reported in flood tolerant and sensitive genotypes. Flooding decreased

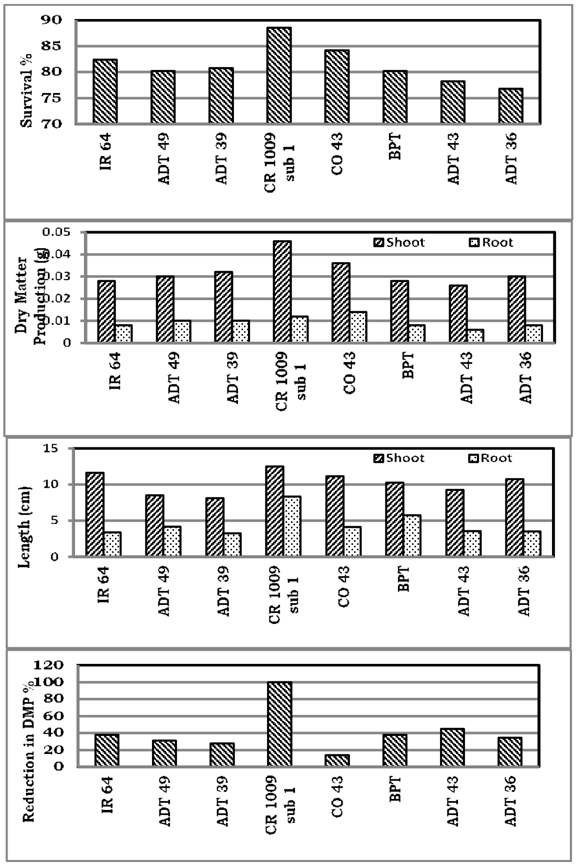

Fig 2: Effect of flooding stress (2 cm) on germination and seedling attributes

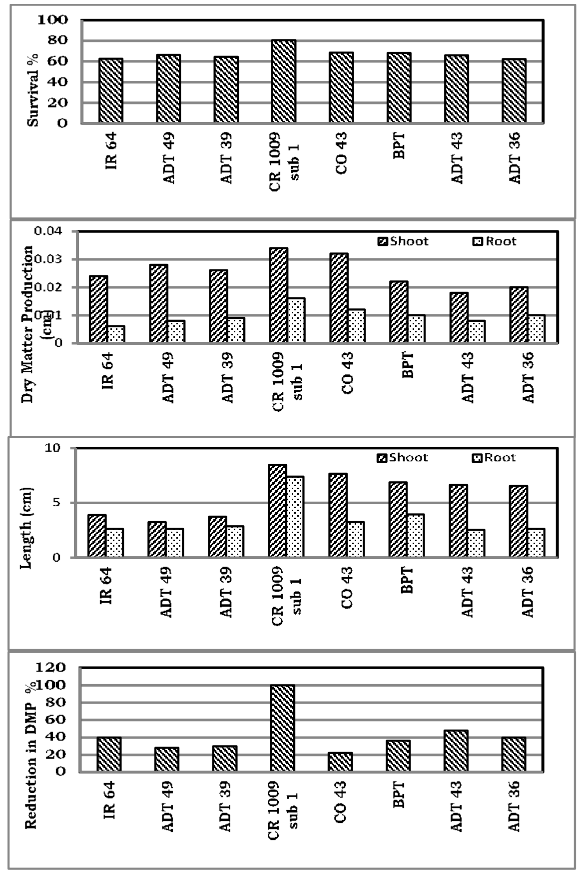

Fig 3: Effect of flooding stress (3 cm) on germination and seedling attributes

root and shoot lengths in both tolerant and intolerant genotypes, with a greater decrease in intolerant ones, i.e., sensitive and tolerant genotypes recorded 81 % versus 61 % decrease for shoot lengths and a 68 % versus 7 % decrease for root lengths respectively. Shoot extension rate of the tolerant genotypes then increased with time after day 4, whereas that of the sensitive types remained slow through to the 8th day (Ismail *et al*., 2009). Similar trend was observed in root growth but it showed delayed trends compared with shoot growth in both tolerant and sensitive lines. In tolerant lines, roots started to appear earlier than in intolerant lines and also found that their growth became faster (Ismail *et al*., 2009)

Dry matter production: Flooding decreased shoot dry matter production, root dry matter production and hence Total DMP in all the varieties which was more pronounced in higher flooding (5 cm) (Fig 5) rather than lower flooding (1cm) (Fig 1) levels. Among the tested varieties, higher DMP was recorded by CR1009 sub 1 (0.060-0.040 gseedling^{-1}) followed by CO 43(0.050-0.038 g seedling^{-1}). All other varieties performed moderately. Reduction in DMP was more pronounced in 5 cm flooding with gradual increase upto 1 cm flooding. ADT 43, IR64 and ADT 36 recorded more reduction in DMP in all the flooding levels whereas CO 43 recorded least reduction in all flooding levels.

The fresh and dry weights of the maize plant were significantly reduced in flooding treatments (Bridget 2003). Under prolonged flooding, flood-intolerant LA1579 plants drastically reduced their morphological and physiological activity and were killed in a short time, whereas flood-tolerant CLN2498E, and CA4 plants withstood the harmful effect of flooding by maintaining their morphological and physiological activities intact and by producing a larger yield (Vincent Ezin *et al*., 2010). All the growth parameters viz., plant height, leaf number, the fresh and dry weight of the plant and the chlorophyll content of the leaves were significantly reduced by flooding stress when compared to the control (Bridget 2003). Drew (2000) and Onwuegbuta-Enyi (2004) also reported that changes in environmental conditions of a plant can cause changes in its physical and chemical properties.

Among the eight varieties tested under five flooding levels, more reduction in all the parameters were observed at higher levels of submergence, with less reduction in tolerant genotypes.

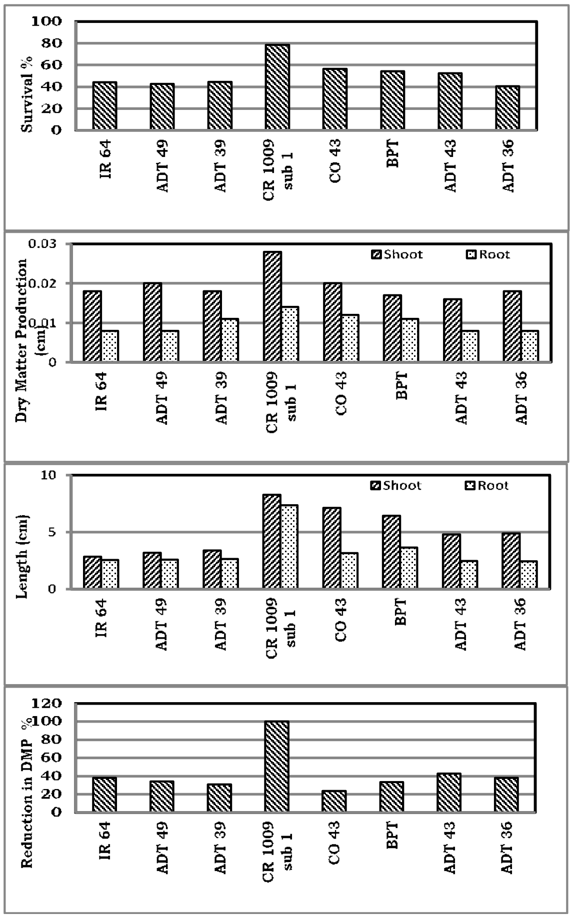

Fig 4: Effect of flooding stress (4 cm) on germination and seedling attributes

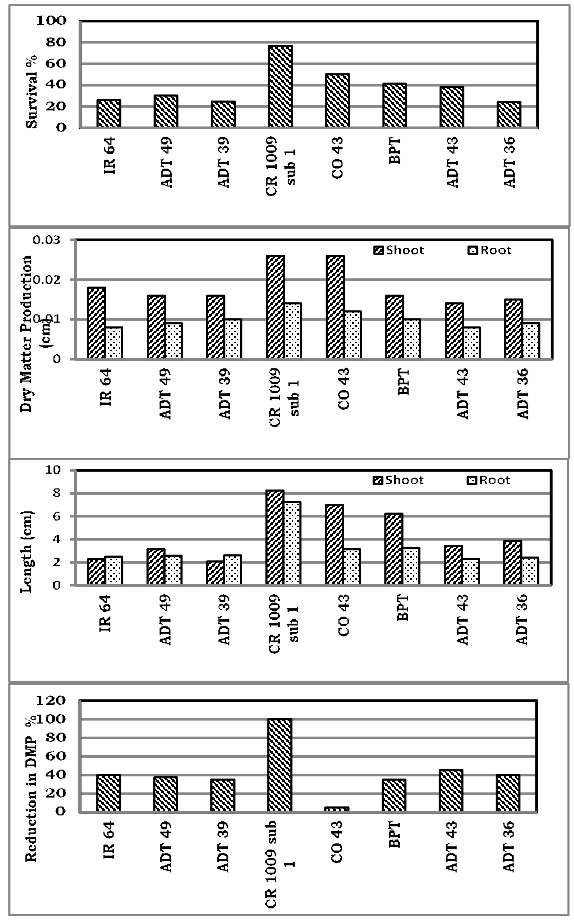

Fig 5: Effect of flooding stress (5 cm) on germination and seedling attributes

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