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Corresponding Author
K. Ashok Kumar
e-mail: koilakondaashok@gmail.com

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"Iron-coated Seed" Technology - a Strategy for Improving Seedling Establishment in Direct Seeded Rice

K. Ashok Kumar[1*] and B. Sahadeva Reddy[2]

Abstract

In recent years, there has been a considerable shift from transplanted method to direct seeded rice cultivation in several rice growing countries. This trend is principally driven by water scarcity issues, expensive farm labour for transplantation and acute shortage of labour. Despite many advantages with direct seeded rice, certain problems associated with this method like inconsistent seedling establishment and heavy weed infestation need attention. This paper focuses on the strategy for improving seedling establishment through "Iron-coated seed" technology. In this method, pre-germinated seeds are granulated with a mixture of reduced Fe powder and calcined gypsum. The iron-coated seeds are prepared through the oxidation of reduced Fe on seed surface forming rust, which serves as a binder for the formation of a hard coating layer. The high density iron-coated seeds are resistant to bird damage, low/no floatation, minimize seed-borne diseases and efficiently improve anchorage in water/wet seeding in puddled fields.

1. Introduction

In the context of looming water crisis and increasing farm labour scarcity, exacerbated by COVID-19 pandemic; and rising cost of cultivation, Direct Seeded Rice method (DSR) has received much attention because of its low-input demand and high water use and rice production efficiency. The DSR method of rice cultivation is steadily gaining ground among the farming community in traditional rice growing areas, particularly in the aftermath of the lockdown. DSR refers to the process of establishing a rice crop from seeds sown in the field rather than transplanting seedlings raised in nursery. The three principal methods of DSR are: dry seeding (dry seeds sown in dry soil), water seeding (seeds sown into standing water) and wet seeding (pre-germinated seeds sown on wet puddled soil) (Kumar and Ladha, 2011) (Figure 1). Inspite of many advantages with DSR, crop stand establishment influenced by rate, uniformity and seedling emergence percentage has become a major deterrant for subsequent growth, development and yield. The poor

Author's Address
[1]Dept. of Agronomy, [2]Dryland Agriculture & Head, Agricultural Research Station, Ananthapuramu, Acharya N.G. Ranga Agricultural University, Andhra Pradesh, 515 001, Lam, Guntur, Andhra Pradesh

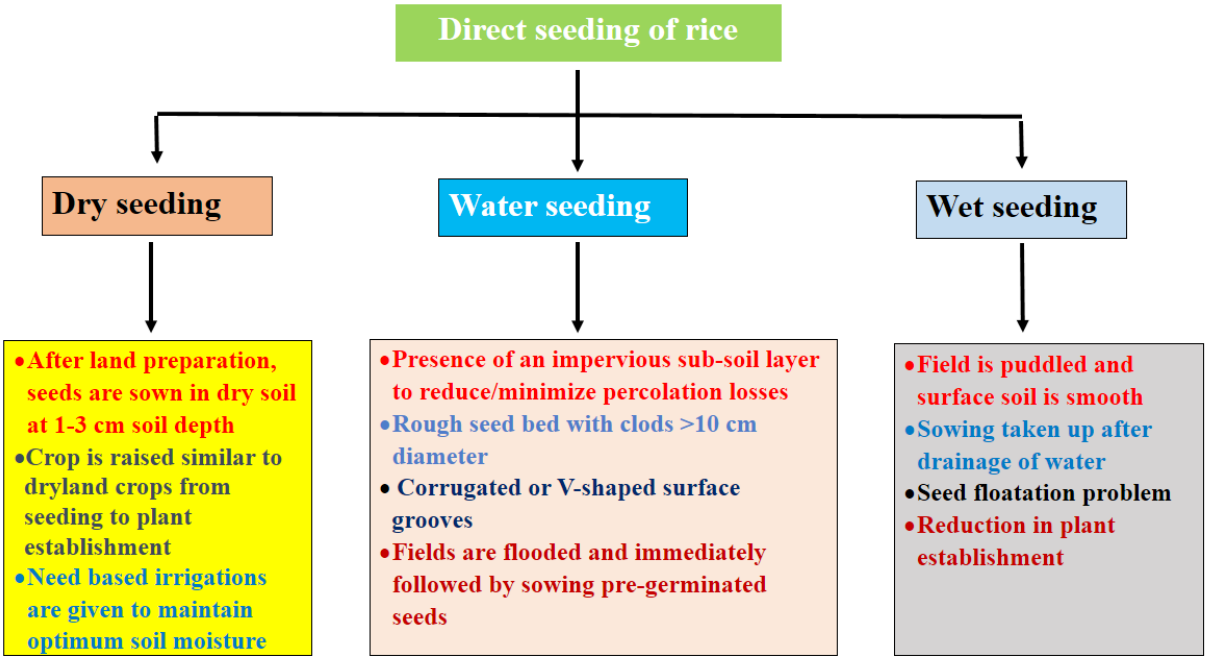

Figure 1: Classification of direct seeding of rice seed

seedling establishment in DSR is due to the decrease in soil redox potential which affects the germinating seeds (Ponnamperuma, 1984). Further, directly sown seeds are vulnerable to bird attacks in the field that results in significant crop establishment losses. In addition, floating of seeds is a major cause for poor plant stand in wet seeding as the surface of puddled soil is smooth and the density of seeds is not large enough to prevent floating and hence, plants to fail to root and anchor (Tuong et al., 2000). In wet seeding, pre-germinated seeds are used as they germinate faster than dry seeds and are superior in landing and settling on the flooded soil surface due to higher density (1.3 Mg m^{-3}) due to soaking as compared to dry seeds (1.0-1.1 Mg m^{-3}). However, the disadvantage of pre-germinated seeds are they have to be prepared just before seeding, germination progresses too far if seeding is delayed. Seed coating can be one of the important complementing technologies to eliminate the risks associated with DSR. Hence, the problems of poor crop stand, bird attack and floatation can be addressed through "Iron-coated seed" technique (Yamauchi, 2010).

2. "Iron-coated Seed" Technology

Iron coating of the rice seed surface is intended to increase the specific gravity to minimize the number of floating seeds and seedlings, when the rice seeds are directly seeded in paddy fields. The "Iron-coated seed" technology was first proposed in 2004 (Yamauchi, 2004) and has been improved iteratively through the modification of the procedure according to its performance in the farmer's fields. The procedure described by Yamauchi et al. (2016) is detailed in Figure 2. The iron-coated seeds are prepared in the following steps.

Granulation

The rice seeds were coated with a mixture of Fe powder and calcined gypsum as an inner layer and with calcined gypsum alone or silica gel as an outer layer. The process of granulation can be done either manually in case of limited seed quantity or through mechanical means for large scale seed quantity. The seeds were rolled in a pan granulator or a concrete mixer (drum capacity 110 litre for 40-80 kg seed), whose mixing blades were removed from the drum. The optimum particle size of Fe powder suitable for granulation is <100 µm. The amount of iron used for coating seed is expressed as iron-coating ratio i.e. weight of the reduced Fe to the weight of rice seeds and the optimum iron-coating ratio is 0.5. The calcined gypsum with high water holding capacity (73%) is mixed with Fe powder @ 0.1 kg kg^{-1}. The powdery mixture of Fe powder and calcined gypsum is made to adhere to seed surfaces by spraying water on the rolling seeds in the granulator. Generally, the quantity of water sprayed is @0.27 -0.12 kg kg^{-1} of Fe powder, which is determined by the properties of Fe powder and seed moisture content.

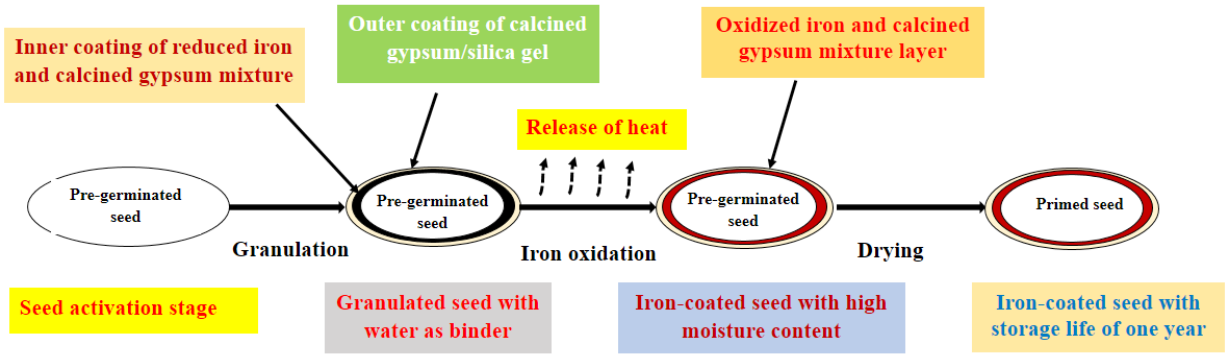

Figure 2: Process of iron-coating of rice seed

Seeds coated with with mixture of Fe powder and calcined gypsum, may adhere to other coated seeds forming blocks during oxidation of Fe powder. Hence, to prevent blocking effect, the seeds need to be coated with calcined gypsum @ 0.05 of the Fe powder weight as outer layer. Also, silica gel can be used as an alternative to calcined gypsum for outer layer coating. The silica gel with a mean particle size of 4-11 µm and pore size 7-21 nm can be used @ 0.015 kg kg^{-1} of the seed dry weight.

Iron oxidation, heat release and drying

The oxidation of reduced Fe powder in the inner seed coating results in heat generation. The generated heat must be discharged so that the seed temperature is <40°C for maintenance of seed viability. The temperature of the seed depends on the balance between heat generated and its discharge, which in turn depends on the seed container shape, reduced-Fe powder properties, moisture content in the granulated seeds and the weather conditions (temperature, humidity and wind speed) at the working site. In general, heat generation is less with low iron-coating ratio. The generated heat can be dissipated by spreading the granulated seeds on platform and exposing the seeds to air. The oxidation process is reduced with evaporation of water from the granulated seeds. The nursery boxes used for raising rice seedlings for mechanical transplanting can be used for spreading the granulated seeds and are to be air-dried atleast for one week. Further, the seeds when stored in plastic bags, the seed moisture content should be below 130g kg^{-1} to avoid temperature increase over 40°C (Shiratsuchi et al., 2012).

3. Cultivation with Iron-coated Seeds

➢ Iron-coated seeds can be directly seeded on to the water-covered soil either by broadcasting on row seeding after settlement of soil particles in puddled field so that seeds are properly positioned on the soil surface.

➢ No soaking or incubation is required before sowing.

➢ A seed rate of 50 kg intact seeds ha^{-1} is required for direct seeding.

➢ Irrigation after seeding iron-coated seeds is given in the same way as for direct seeding with pre-germinated seeds.

➢ The field is surface drained at coleoptile emergence and is reflooded after rooting and first leaf emergence. However, need based intermittent/flash irrigation is to be provided after direct seeding with iron-coated seeds to avoid dessication of seed due to soil dryness (Sato et al., 2011) or increased seed temperature due to prolonged exposure to sunlight.

➢ Weed control and plant protection measures in fields sown with iron-coated seeds can be taken up in the same way as per the recommendations in direct seeding/ transplanted rice.

4. Characteristics of Iron-coated Seeds

4.1. Seed density

Iron-coating significantly influenced the seed density ranging from 1.1 to 3.1 Mg m^{-3} with iron-coating ratio between 0 (non-coating) and 4. A seed density of 1.2 Mg m^{-3}, that is attained through genetic improvement or selection with salt water could be obtained with a Fe-coating ratio of 0.08 and a seed density of 1.6 Mg m^{-3} is achieved with an optimum iron-coating ratio of 0.5, which cannot be obtained biologically. Hence, iron-coating is an efficient strategy for enhancing seed density.

4.2. *Bird control*

In direct seeding of rice, protection of sown seeds from bird attack is essential for successful plant stand. Research studies indicated that the magnitude of bird damage was

reduced with increasing the iron-coating ratio (Chikawa et al., 2014) from 0.5 to 1.0. The reduced bird damage was due to the higher mechanical strength offered by the iron-coated seeds and was not due to repellent action.

4.3. *Control of seed borne diseases*

Iron-coated seeds were effective in suppressing the occurrence of seed borne diseases *viz.*, bacterial seedling blight, bakane disease, brown spot and rice blast. In addition, iron-coated seeds reduce the viability of white tip nematode and there by reduces its incidence. The suppression of disease incidence was contributed to the active oxygen evolved from iron-coated layer (Fujiwara et al., 2012) and was equivalent to that of chemical disinfectants at iron-coating ratio of >0.25.

Also, the dried iron-coated seeds could be prepared manually or mechanically in large quantities and stored for more than 1 year at room temperature.

5. Safety Concern of Iron Use

Many research studies indicated that there are no adverse effects on environment with usage of Fe powder in rice production. Moreover, soil inherently contains iron to an extent of 30-40 kg ha^{-1} depending on soil type. Further, reduced Fe is used for domestic purposes as a body warmer and industrial use as oxygen absorbent in food industry. Also, iron containing slag is used as soil amendment applied at 340 kg ha^{-1}. With iron-coated seed technology, the amount of iron applied to the field at iron-coating ratio 0.5 is 25 kg ha^{-1}, which is very minimal as compared to inherent soil iron.

6. Conclusions and Future Perspectives

Besides protecting seeds from bird attack and proper settling of seeds on puddled soil surface, this technology serves as a delivery system for biological and chemical treatments for enhancing seed/seedling performance. The method of incorporation of beneficial material like pesticides as seed treatment in to seed coating layer reduces pesticide usage and labour. As the shifting from transplanted to DSR is due to labour shortage besides water scarcity, studying this technology widely in view of water conservation is required.

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