Introduction

Rice is produced worldwide and is the primary staple for more than half the world's population. The eight countries with the most rice area are all in South and Southeast Asia (India, China, Indonesia, Bangladesh, Thailand, Vietnam, Myanmar, and the Philippines) and they have 80 per cent of the global rice area. Almost half the global rice area is in India and China and 89 per cent is in Asia. Demand for food grains in India is expected to grow and the requirement for 2025 is estimated to be a 40 per cent production increase compared with 2003-04. In the near future, the possibility for expanding areas under rice-based systems will remain very limited because of the scarcity of water resources for agriculture, the expansion of urban and industrial sectors where land is already limited and the high costs of developing new lands that are suited for rice production.

Water requirement in rice cultivation

Asia, where agriculture accounts for 86 per cent of total annual water withdrawals compared with 38 per cent in Europe and 49 per cent in North and Central America. The per capita availability of water resources declined by 40 per cent to 60 per cent in most Asian countries from 1955 to 1990 (Gershon and Keck, 1994). Worldwide, about 79 million ha of irrigated lowlands provide 75 per cent of the total rice production. Lowland rice is traditionally grown in bunded fields that are continuously flooded from crop establishment to close to harvest. It is estimated that irrigated lowland rice receives some 34-43 per cent of the total world’s irrigation water, or 24-30 per cent of the total world’s freshwater withdrawals. Currently, 31 countries are facing water shortages, a number that is expected to increase to 48 countries by 2025, peaking at 55 countries by mid-century, 2050. The growing water shortage means there is a pressing need to devise methods of growing rice with less water, without any penalty to production. Kandasamy and Sivaperumal (1997) reported a saving of 298.8 mm of water under direct sown crop, which was 22.1 per cent less than the amount used by transplanted crop.
Shift in crop establishment method - Direct Seeded Rice

The change in rice crop establishment from transplanting to direct seeding has occurred in many Asian countries because of rapid economic growth, increasing labour costs, and shortages of water. In addition, there is a need to reduce the costs of rice production in order to maintain profitability despite the declining trends in market price, a trend that is expected to continue in the future. Direct seeding method reduced labour hours by 69 per cent (183 to 57 hr ha\(^{-1}\)) and production cost by 59 per cent was noticed in a study conducted in Korea. All over the world, it has been proved that yield potential under wet direct seeding is even higher than that of the age old practice of transplanting (De Datta, 1980).

Direct seeded rice in India

In India, too, direct-seeded rice is practiced in parts of several states, including Karnataka, Kerala, Tamil Nadu, Orissa, Andhra Pradesh, Chattisgarh, Bihar, West Bengal, and the hill state of Uttaranchal. Under direct seeding, wet sowing is gaining importance and acceptance by the farmers due to its yield potential.

Weed management in direct seeded rice

Weed infestation is a major threat to yield and the further expansion of direct seeding. A mix of cultural practices, water management, herbicides, and manual or mechanical weeding methods can be used to manage weeds in direct-seeded rice. Productivity of the direct seeded rice crop largely depends on timely weed management practices. Yield losses from uncontrolled weed growth in direct seeded rice are much higher compared to transplanted rice. Management of weeds very early in the rice season holds the key for a successful direct seeded rice crop. In direct-seeded upland rice (*Oryza saliva* L.) yield reductions due to weed competition ranged from 42 to 65 per cent in field experiments conducted in eastern Uttar Pradesh, India. Weeds cause severe damage to direct seeded rice and yield may be reduced to an extend of 50-60 per cent, sometimes complete crop failure due to weed infestation.
Seed rate in direct seeded rice

The initial population establishment is an important factor deciding the yield potential of direct seeded rice. For this the desired and required seed rate should be followed. The seed rate naturally influences the growth of the seedlings. Seeding rate was inversely correlated to weed interference. Severe rice yield reduction (71%) caused by weeds was found at a seeding rate of 40 kg seed ha$^{-1}$ in the wet season (Phuong et al, 2005). Essentially, growers are recommended to plant twice as many seeds as needed for optimum rice density, and an even greater rate if planting in a clay soil or under imperfect seedbed conditions (Wilson et al., 2005).

Herbicides and Weed Management

The importance of herbicide use in the tropics is closely related to the cost and availability of labour. Hand weeding which has better weed control efficiency, is laborious, time consuming and expensive and it is quite difficult in wet seeded rice due to high density rice population in this system (Singh et al, 1999). Herbicides are one of the first labour saving technologies to be adopted for minimising labour costs rise. Herbicides replace hand weeding and enable direct seeding rather than transplanting. Direct seeding in the lowlands is linked to the use of herbicides, as without their use the weeds grow so rapidly in the stages before the fields can be flooded, that manual means of control are often not feasible. Associated with direct seeding is an inevitable shift in the weed flora toward competitive grasses, including *Echinochloa* species, *Leptochloa chinensis*, and *Ischaemum rugosum* in wet-seeded rice and in dry-seeded rice the perennial sedge *Cyperus rotundus*. Management of such weeds requires farmers to have the ability to anticipate changes in weed populations and, to reduce losses, exploit integrated strategies comprising tillage, water, and crop management to complement herbicide application.

To control weed efficiently, herbicide should be applied systematically. Many farmers are however not fully aware about their proper and correct use against diverse weed flora. Currently many choices are not available in India but in near future it will be realistic to our farmers. With the high development costs for new herbicides, the agrochemical industry currently focuses on novel uses and mixtures of current active ingredients in order to solve new weed problems associated with direct-seeded rice.
With these backgrounds the present study was undertaken with the following objectives

- To optimize the seed rate of direct seeded rice under wet condition.
- To find out the ideal weed management practices for direct seeded rice.
- To find out the interaction effect of seed rate and weed management practices.
- To work out the economics of different seed rate and weed management practices of direct seeded rice,
- Test verification of effective treatments in large plots.
- Bioassay study on residual crop