

Performance of non puddled transplanted summer rice (*Oryza sativa* L.) cultivars under different moisture regimes

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Orissa University of Agriculture and Technology
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(Agronomy)*

By

***SUBHASHREE KAR
Adm. No. 12AGRO/14***



**DEPARTMENT OF AGRONOMY
COLLEGE OF AGRICULTURE
ORISSA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY
BHUBANESWAR- 751003, ODISHA
2017**



**DEPARTMENT OF AGROMETEOROLOGY
COLLEGE OF AGRICULTURE
ORISSA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY
BHUBANESWAR-751003, ODISHA**

Dr. B. S. Rath
Professor and Head

Bhubaneswar
Date:

CERTIFICATE - I

This is to certify that the thesis entitled “**Performance of non puddled transplanted summer rice (*Oryza sativa* L.) cultivars under different moisture regimes**” submitted in partial fulfilment of the requirements for the award of the degree of **MASTER OF SCIENCE IN AGRICULTURE (AGRONOMY)** of the Orissa University of Agriculture and Technology, Bhubaneswar is a faithful record of *bona fide* research work carried out by **SUBHASHREE KAR** under my guidance and supervision. No part of the thesis has been submitted for the award of any other degree or diploma.

It is further certified that the assistance and help availed by her from various sources during the course of investigation has been duly acknowledged.

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COLLEGE OF AGRICULTURE
ORISSA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY
BHUBANESWAR-751003, ODISHA

CERTIFICATE-II

This is to certify that the thesis entitled “**Performance of non puddled transplanted summer rice (*Oryza sativa* L.) cultivars under different moisture regimes**” submitted by **SUBHASHREE KAR** to the Orissa University of Agriculture and Technology, Bhubaneswar in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE IN AGRICULTURE (AGRONOMY)** has been approved by the students’ advisory committee and external examiner.

Advisory committee

Chairman: **Dr. B. S. Rath**
Professor and Head
Dept. of Agrometeorology

Members:

1. **Dr. B. Behera**
Professor and Head
Department of Agronomy

2. **Dr. B. K. Mishra**
Former Professor and Head
Department of Plant Physiology

3. **Dr. C. M. Khanda**
Professor (Agronomy)
Now Assoc. Director of Research
RRTS, Bhawanipatna

External Examiner

(Name and designation)

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Place: Bhubaneswar
Date:

(Subhashree Kar)
Adm. No.12 AGRO/14

ABSTRACT

A field experiment was conducted during summer season of 2015-16 to study the “Performance of non puddled transplanted summer rice (*Oryza sativa* L.) cultivars under different moisture regimes” at Agronomy Main Research Farm, Orissa University of Agriculture and Technology, Bhubaneswar. The experiment was laid out in Alpha lattice design with 24 summer rice cultivars (Shahabhazi, Mandakini, Khandagiri, ADV 1417, DRR Dhan 42, DRR Dhan 43, US-321, US-323, US-359, Naveen, Konark, CR Dhan 201, CR Dhan 202, CR Dhan 204, Arize 6129, Ajay, Rajlaxmi, Lalat, US-366, US-395, DRR Dhan 44, CR dhan 701, Arize 6444, Arize Prima) as first factor and moisture regime (0 kPa- non stressed and 40 kPa- stressed) as the second factor. The soil of the experimental site was sandy loam with pH of 5.8, EC of 0.040 dSm⁻¹, organic carbon 0.41%, available N 245.2 kg ha⁻¹, available P 43.4 kg ha⁻¹, available K 166.8 kg ha⁻¹. The experimental result indicated that the cultivars Shahabhazi and US-323 among the 100 days duration cultivars, CR Dhan 202 among the 115-120 days cultivars, US-395 among the 125-135 days cultivars and Arize 6444 among the cultivars of 135-144 days duration recorded grain yield at 40 kPa (stressed) of moisture regime which is at par with the grain yield obtained from the 0kPa (non-stressed) of moisture regime. This indicated that these cultivars were stress tolerant amidst the total number of 24 cultivars. The above mentioned cultivars required the same GDD in the 40kPa (stressed) moisture regime as the one in the 0kPa (non-stressed) moisture regime and there was non significant difference in shortening of duration of the cultivars which clearly state the fact that there was no sign of forced maturity of these specified cultivars under the moisture regime of 40 kPa. Among the early duration varieties highest grain yield was recorded in US 323 of 4.2 t ha⁻¹ which was statistically at par with the grain yield of Shahabhazi that produced 4.0 t ha⁻¹, in the mid early cultivars category highest grain yield was witnessed from CR Dhan 202 with 3.8 t ha⁻¹, among the medium duration cultivars US-395 exhibited the highest grain yield of 6.96 t ha⁻¹, Arize 6444 topped the list among the mid late duration cultivars with the grain yield of 6.7 t ha⁻¹. The total irrigation water applied was (18 no.s) 90 cm in the 0 kPa moisture regime and (14 no.s) 70 cm in the 40 kPa moisture regime. Maximum B:C ratio of 1.8 was obtained for US-323 among the early duration cultivars, 1.66 for CR Dhan 202 among the mid-early duration cultivars, 1.81 for US-395 among the medium duration cultivars and 1.72 for Arize 6444 among the mid late duration cultivars.

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INTRODUCTION

Rice is the staple food for about one half of the world's population. This grain has origins going back to about 3000 B.C in India, and grew along the rivers of Tigris and Euphrates circumscribing the ancient civilizations of Mesopotamia. The eastern nations like China, India, Japan, Bangladesh, Indonesia, Thailand and Burma are the major producing hubs of the world. 482 million metric tones of husked rice was produced in 2016 in the global scenario and the global consumption of milled rice amounted to approximately 478.44 million metric tones (FAO, STAT, 2016-17). Rice is much more than a grain, it has fueled economies, been subject to science, and travelled the globe due to world trade.

The demand of rice as staple food for about 3 billion people is expected to increase further with increase in population. Globally rice is grown in 162.3 mha, and India accounts for 27.47% with a cultivated area of 44.6 mha, the corresponding production being 738.1 and 104.20 Mt. The average productivity under Indian condition is 2.44t ha⁻¹ compared to the world's average of 4.5t ha⁻¹(CACP, 2016). Odisha occupies an area of 4.41 m ha producing 6.94 Mt with an average productivity of 1.57 t ha⁻¹, 35.56% less than the national average(Govt. of Odisha, 2016-17).

With its ability to adopt itself to a wide range of geo-hydrological situations, rice enjoys a unique place among the field crops. Based on two major environmental determinants of source of water and degree of flooding, rice can be grouped under different ecosystems such as rainfed upland, rainfed low-land, medium land, deepwater and tidal wetlands. In spite of its wider adaptability and cultivation, we have still not achieved the position to balance rice production under these ecosystems for obtaining higher and sustainable yield.

Conventional puddled transplanting is the wide spread establishment method of rice which maintains 5-10 cm of deep standing water throughout its growth period. The resultant high water table, soil compaction and post harvest soil management has not only deteriorated the soil environment, but also resulted in water scarcity that has given a major threat to rice production. Excessive pumping of water for puddling in peak summers in north west Indo-gangetic plain resulted in declining water table. However, in recent years, depleting water resources governed by climate change and labour shortage are threatening the sustainability and productivity of transplanted-flooded rice. Tuong and Bouman (2003) reported that, in Asia, 39 million ha of irrigated rice may suffer from "physical water

scarcity” or “economic water scarcity” by 2025. Compared with other cereal crops such as wheat and maize, transplanted-flooded rice consumes two or three times more water. Transplanted-flooded rice leads to high losses of water through puddling, surface evaporation and percolation (Farooq *et al.*, 2011). Chauhan *et al.*(2012) reported that puddling in transplanted-flooded rice systems consumes up to 30 % of the total rice water requirement. Although, puddling is favorable in rice–rice cropping systems, as it reduces soil permeability, creates hardpans and reduces water losses through percolation. Nonetheless, repeated puddling operations negatively affect the non-rice upland crop in rotation (McDonald *et al.*, 2006) by dismantling soil aggregates, reducing permeability in subsurface layers, and forming hardpans at shallow depths (Sharma *et al.*, 2003). Non puddled transplanted rice has been believed to be an optimal option for rice production (Kumar *et al.*, 2011). Omission of puddling improved soil physical properties such as bulk density, penetration resistance, aggregation stability and cracking behaviour. The absence of soil disturbance also improved soil aggregation, average mean-weight diameter and water stable aggregates. Thus, non puddle conditions increased the macro-aggregate fraction by 18 -33%. Non puddled treatments recorded slightly higher nutrient contents in the top soil. (Mondal *et al.*, 2016)

To meet the major challenge of increasing rice production to feed a growing population under increasing water scarcity, many water-saving regimes have been introduced in irrigated rice, such as an aerobic rice system, non-flooded mulching cultivation and alternate wetting and drying (AWD). These different moisture regimes could substantially enhance water use efficiency (WUE) by reducing irrigation water. Yang *et al.* (2016) states that moderate AWD, in which photosynthesis is not severely inhibited and plants can rehydrate overnight during the soil drying period, or plants are re watered at a soil water potential of –10 to –15 kPa, or mid day leaf potential is approximately –0.60 to –0.80 MPa, or the water table is maintained at 10 to 15 cm below the soil surface, could increase not only WUE but also grain yield. Increases in grain yield and WUE under moderate AWD are due mainly to reduced redundant vegetative growth, improved canopy structure and root growth, elevated hormonal levels, in particular increases in abscisic acid levels during soil drying and cytokinin levels during rewatering; and enhanced carbon remobilization from vegetative tissues to grain. Moderate AWD could also improve rice quality, including reductions in grain arsenic accumulation and reduce methane emissions from paddies.

Moisture stress is the most important abiotic constraint that reduces yield in rainfed areas and contributing to 15 per cent loss in rice production annually in India (Dey *et al.*, 1996).

The average yield in rainfed areas is low because of periodic moisture stress and adverse soil physico-chemical conditions and lack of improved varieties (Mall *et al.*, 2011). Moisture stress resistance appears to be the single most important factor in increasing and stabilizing rice production under rainfed areas (O'Toole *et al.*, 1982). Genetic studies show that adaptive mechanisms to moisture stress in rice are heritable and controlled by complex quantitative characters (Kumar *et al.*, 2008). The most widely used criteria for selecting high yield performance are mean yield in moisture stressed and favorable environment. Ahmad *et al.* (1999) found grain yield to be a useful criteria for assessing moisture stress response of genotype.

Research programme was initiated during 1970 to develop hybrid rice varieties in the country. In India, more than 1020 rice varieties have been released for cultivation in different ecosystems (Directorate of Rice Research, Hyderabad). Out of these, NRRI (National Rice Research Institute) and OUAT (Orissa University of Agricultural Science and Technology) has developed 114 and 62 varieties respectively. Proper choice of rice variety for a particular ecology, is very important to realize high production. This triggers the need to evaluate the suitable cultivars for Odisha condition under moisture stress developed by the various research institutes and state agricultural universities. With this background a field experiment was conducted on "Performance of non-puddled transplanted summer rice cultivars under different moisture regimes" where twenty four cultivars of varying durations were screened to reveal the best performing variety in various cluster of duration. The twenty four cultivars were from National Rice Research Institute, Cuttack, Odisha, Directorate of Rice Research, Hyderabad, Orissa University of Science and Technology, Bhubaneswar and some of the leading cultivars of the Private sector. The objective of the experiment was to

1. To study the behavioural response of crop phenology of summer rice cultivars under two different moisture regimes (0 and 40 kPa)
2. To study the growth and yield of summer rice cultivars under two different moisture regimes (0 and 40 kPa)
3. To calculate the irrigation water requirement under different moisture regimes (0 and 40 kPa).



REVIEW OF LITERATURE

Rice is the important primary cereal crop in the world. It is the staple food for more than two-third of the world's population (Dowling *et al.*, 1998). Biotic and abiotic factors limit adversely the productivity of the rice growing areas of the world. It has been estimated that more than 200 million tons of rice are lost every year due to environmental stresses, diseases, and insect pests (Herdt, 1991; Chen and Murata, 2002). Moisture stress, that affects plant growth, is a major constraint for about 50% of the world production area of rice. Drought effects in lowland rice can occur when soil water content drops below saturation (Bouman and Tung, 2001). Some researchers reported that rice crop is susceptible to drought, which causes large yield losses in many Asian countries (Jearaknognman *et al.* 1995; Bouman and Tung 2001; Pantuwan *et al.* 2002), however, some genotypes are more drought resistant than others, out yielding those exposed to the same degree of water stress. Hence, present investigation was carried out to elucidate which rice cultivars can achieve higher yield than others under water limiting conditions in different growth stages, with particular emphasis on tillering, yield, yield components and harvest index. In this chapter an attempt has been made to critically review the research works carried out on “Performance of non puddled transplanted summer rice cultivars under different moisture regimes.”

The literature collected on these aspects have been presented under the following subheads:

- 2.1 Effect of different moisture regimes on the growth and yield of rice crop
- 2.2 Performance of different rice cultivars
- 2.3 Interaction effect of different moisture regime and variety on the yield of the rice crop.

2.1 Effect of different moisture regimes on the growth and yield of rice crop

Puckridge *et al.* (1981) have shown that biomass production of rice is a function of water use. The shortage of water in the soil suppresses the leaf expansion, tillering and photosynthetic rate along with leaf area due to senescence. All these factors are responsible for reduction in dry matter accumulation.

A field experiment was conducted in which rice was grown aerobically (T1), flooded for the entire growth period (T2) or flooded for two weeks after transplanting, given supplemental irrigation up to panicle initiation and then flooded from panicle initiation to physiological maturity (T3). The study showed that rice crop exhibited significantly reduced growth in term of Leaf Area Index (LAI), Crop Growth Rate (CGR), Total Dry Matter accumulation (TDM) and Net Assimilation Rate (NAR) when it was grown in aerobic condition. However, the crop was not affected significantly different from normal flooded rice (T2) when it was grown in modified rice culture (T3) (Sarwar *et al.*, 2013).

Talpur *et al.* (2013) reported that 5 cm is optimum water depth for vegetative and mid stage of the rice crop growth, while 10 cm water depth is appropriate for harvesting of the rice crop and the same (10 cm) is found suitable for maximum yield.

Hazra *et al.* (2016) studied the effect of variable degrees of water stress namely no-stress, mild-stress and prolonged-stress imposed throughout the crop growth by using two contrasting varieties namely Binadhan-8 and Iratom- 24.. Mild and prolonged stress during late vegetative stage (45–75 days after transplanting) in Binadhan-8 greatly enhanced (30.3–41.5 %) crop growth rate while, any level of stress during reproductive phase in Iratom- 24 reduced (8.8–10.8 %) rate of crop growth.

The canopy temperature of rice at the flowering stage and the soil water content were investigated under different soil water treatments (the soil water contents were 24%, 55%, 90% and 175% at the flowering stage). The lower the soil water content, the higher the canopy temperature. Under the lowest water content treatment, the peak flowering occurred in the first three days (about 70% of panicles flowered), resulting in shorter and lighter panicles with lesser number of grains which ultimately caused low yield (Wen-zhong *et al.*, 2007).

Using two rice cultivars- 2401 (*japonica* rice) and Ilyou107 (*indica* rice) in 2008, Zhejing22 (*japonica* rice) and Ilyou7954 (*indica* rice) in 2009 the effect of severe, mild and no water stress, W3, W2 and W1, respectively, on flag leaf physiology, the ecological characteristics of canopy temperatures were studied by Yan *et al.* (2012). The grain yield and the test weight was reduced under W3 but not

under W2. The canopy temperatures were significantly higher in W3 than in either W1 or W2, and there was no significant difference between W1 and W2. This study clearly showed that water stress had a significant effect on leaf physiology and temperature of canopy.

Saini *et al.* (2000) reported that water stress damages pollen fertility and affected anthers became shriveled, unable to dehiscence and contain sterile pollens. Such pollen grains have dilute cytoplasm and are devoid of starch which is a conspicuous constituent of fertile pollen. Water stress reduces the number of anthers that dehiscence and lowers the amount of pollen shed and *in vivo* pollen germinability. Grain abortion at early stages following fertilization accounts for reduction in grain number.

Yang *et al.* (2001) reported that early senescence induced by a moderate water deficit during grain filling period can enhance the remobilization of stored assimilates and accelerate grain filling of rice.

Plaut *et al.* (2004) reported that water stress during the grain filling period reduces the photosynthesis, induces early senescence and shortens the grain filling period but increases the remobilization of assimilates from straw to grains. Limited water availability can significantly impair photosynthesis.

Deshmukh *et al.* (2007) observed that in rice, water stress during flowering can reduce the harvest index by as much as 60%, largely as a result of a reduction in grain set. Panicles in stress plants fail to fully exert (emerge) from the flag leaf sheath, flowering is delayed and the percentage of spikelets that open at anthesis is reduced. The failure of panicle exertion alone accounts for approximately 25 to 30% of spikelet sterility because the unexerted spikelets cannot complete anthesis and shed pollen, even when development is otherwise normal.

Field studies on dry matter partitioning under drought were conducted at eight locations in Chattisgarh, India using five diverse rice cultivars. Dry matter accumulation at flowering and maturity was significantly reduced in drought-affected sites. Variation was observed among cultivars in dry matter partitioning to grain under both favorable and water-stressed conditions. Drought stress at the reproductive stage significantly increased the dry matter partitioning from leaves and stems to grains in all cultivars. Under drought, dry matter partitioning into green leaves varied among

cultivars, with NSG-19 partitioning the least dry matter to green leaves at maturity. Delay in flowering due to drought stress was negatively associated with grain yield. The contribution of dry matter partitioning from stems and leaves to grain filling increased with the severity of drought stress, particularly in cultivars with an enhanced capacity for leaf senescence during grain filling, which acted to stabilize their grain yields under drought. (Kumar *et al.*, 2006)

Gani *et al.* (2002) studied the effect of different irrigation management (flooded and intermittent irrigation) on rice crop. Results indicated that intermittent irrigation recorded the highest value of yield and yield parameters as compared with flooded irrigation.

Mahto *et al.* (2003) studied regression analysis of 26 early maturing upland rice genotype conducted in a field experiment in Ranchi, Bihar during the *kharif* season of 1995 and observed that grain yield had significant positive association with number of days to 50% flowering, number of panicle plant⁻¹ and number of filled grain panicle⁻¹.

The response of rice (cv. Pant Dhan-4) to various soil water regimes under upland conditions was studied in tarai region of Uttaranchal at the G. B. Pant University of Agriculture and Technology, Pantnagar . Delayed application of 7.5 cm irrigation water 3 days after disappearance from the plot reduced the number of tillers by 11 per cent and grain yield by 16 to 20 per cent over continuous submergence of 5.0 + 2.5 cm irrigation water. Crop maturity was delayed by 8 to 11 days due to change in soil water regimes from continuous submergence to rainfed conditions (Rai *et al.*, 2005).

A field experiment was conducted on aerobic rice during summer season of 2013 and 2014 at Regional Research and Technology Transfer Station, Chiplima, Sambalpur, Odisha by Nayak *et al.* in order to study the effect of irrigation regimes on yield of aerobic rice (Apo). Four irrigation regimes viz., irrigation at 3 days interval, 5 days interval, 7 days interval and 9 days interval were tested.. The result revealed that irrigation at 3 days interval showed the maximum values of grain yield (3.44 t ha⁻¹) but it was at par with irrigation at 5 days interval(3.22 t ha⁻¹). Both the above irrigation regimes significantly have higher grain yield as compared to rest other higher irrigation interval.

A pot experiment was carried out with four Boro rice varieties –Binadhan 5, Binadhan-6, Iratom-24, BRRI dhan-29 to observe grain growth and yield performance under different soil moisture regimes. Moisture levels viz., 5 cm standing water, 100% field capacity (FC) and 80% FC were maintained during booting, flowering and tillering to maturity stages separately for yield performance. Moisture levels viz., 100, 80 and 30% FC were also maintained from panicle emergence to maturity for grain growth pattern. Plant height, tiller number, panicle number, panicle length, number of filled grains per panicle, 1000-grain weight, total dry matter, yield and harvest index were decreased with the less soil moisture. However, varietal responses were different due to different soil moisture regimes for most of the characters and they had different degree of reduction. Binadhan- 5 produced highest yield, more tillers and panicles per plant, highest 1000-grain weight and total dry matter and medium harvest index under different soil moisture regimes. Binadhan-6 showed better yield but the highest total dry matter and medium harvest index. Iratom- 24 showed medium yield, total dry matter and the shortest panicle. BRRI dhan 29 showed the highest harvest index but it produced lower grain yield under different soil moisture regimes (Hossain *et al.*, 2014).

Water-wise rice production is the current concern. To justify whether less water affects rice production, rice plants were cultivated under different water regimes. Four treatments, T1: flooding at 5 cm depth, T2: flooding at 1 – 3 cm depth, T3: saturated to 1 cm flooding, and T4: alternative wet and dry (AWD), were arranged . Treatment of AWD significantly decreased plant height (9%), tiller number ($p \leq 0.04$), panicles number ($p \leq 0.024$), filled grains ($p \leq 0.037$), yield ($p \leq 0.001$) and harvest index (≤ 0.005) but increased unfilled grains ($p \leq 0.011$) compared to the control. Treatment T3 saved 45% of water used in T1 treatment and showed higher water use efficiency (WUE) but produced rice yield similar to T1 and T2 treatments. These results suggested that saturated to 1 cm flooding water could easily be implemented in rice cultivation by the farmers which might not affect rice production (Khairi *et al.*, 2015).

Pascual *et al.* (2016) investigated to determine the effects of crop growth, yield and irrigation water use of two rice varieties, namely Tainan11 (TN11) and Tidung30 (TD30) under the irrigation regimes of (a) intermittent irrigation with three-day intervals (TD303 and TN113); (b) intermittent irrigation with seven-day intervals

(TD307 and TN117) and (c) continuous flooding (TD30F and TN11F). Results showed that intermittent irrigation of three- and seven-day intervals produced water savings of 55% and 74% compared with continuous flooding. Total water productivity was greater with intermittent irrigation at seven-day intervals producing 0.35 kg_{grain}/m³ (TN117) and 0.46 kg_{grain}/m³ (TD307). Average daily headed panicle reduced by 166% and 196% for TN113 and TN117 compared with TN11F, with similar reduction recorded for TD303 (150%) and TD307 (156%) compared with TD30F. Grain yield of TD30 was comparable among irrigation regimes; however, it reduced by 30.29% in TN117 compared to TN11F. Plant height and leaf area were greater in plants exposed to intermittent irrigation of three-day intervals.

The response of rice roots and shoots and their causal relationships affecting yield under varying soil water condition are important related subjects of research. To understand the mechanism of response, studies were conducted using four water treatments: a) intermittent flooding through the vegetative stage (IF-V); b) intermittent flooding extended into the reproductive stage (IF-R); c) no standing water (NSW), maintaining soil at field capacity; and d) continuous flooding (CF) condition at the Asian Institute of Technology in Thailand. It was observed that the senescence of lower leaf and flag leaf was delayed under IF-V compared to CF water condition. This delay was associated with higher biomass production (14% higher than CF) along with higher grain yield (25% higher than CF) (Mishra., 2012).

2.2 Performance of different rice cultivars

Okeleye *et al.* (2002) evaluated the rice cultivar of the short and medium duration upland rainfed and lowland ecologies in the field trial over 4 years (1996-99) to determine suitability for upland and lowland rainfed ecologies. Two cultivars were tested for earliness to demonstrated potential for this trait. They were WAB 32-80 and WAB 56-144-FX2 that mature at 107 days after planting. Performance across the year indicated that adequate soil moisture was an important determinant of grain yield.

Fukai *et al.* (2004) found that there was significant interaction for grain yield among the genotypes grown under the well watered and drought conditions. Early flowering was found to be good mechanism for escaping drought. Yield potential was an indicator of performance under medium drought condition. High yield potential was found mostly in the intermediate flowering genotype of rice.

Yang *et al.* (2005) opined that delayed whole plant senescence was caused by adoption of lodging-resistant cultivars- Wuyujing 3 (*japonica*) and Yangdao 4 (*indica*) in water stress conditions that remain green when the grains are due to ripen results in a low harvest index with much nonstructural carbohydrate (NSC) left in the straw.

The study by Serraj *et al.* (2012) explores the feasibility of using hybrid rice technology in drought-prone rainfed lowland fields. Hybrid lines, parental inbreds, and cultivated varieties as checks were screened for yield potential in well-watered fields and for drought resistance in drained fields at different stress levels. Nineteen out of 45 hybrid lines showed a yield advantage (on average 20%) over check lines in the three well-watered environments. Classifications of drought stress levels were based on the yield reduction relative to the well-watered environments, with moderate, severe, and very severe stress levels resulting in 54%, 77% and 89% reductions in yield respectively. Among the hybrid rice lines, one cluster including IR81954H, IR81955H, and IR81956H stood out as combining high yield potential in both well-watered and drought stress environments. Hybrid IR81954H showed an 8% yield advantage over other hybrids across all studies, as well as stable yield in all the stress environments having an average yield advantage of 22% over other hybrids averaged across drought environments.

A study was conducted using eight rice genotypes of diverse origin to explore their response against variable drought stress. Two water stress treatments for one week and two weeks were given sixty days after seeding. Significant differences among genotypes and water stress levels were observed from phenotypic performance. Correlation studies indicated a positive and significant association of paddy yield with spikelet fertility and 1000 grain weight. Rice genotype IR55419-04 showed least effect of water stress treatments for 1000 grain weight i.e., 6.28% and 10.44% reduction, spikelet fertility percentage with 19.99% and 40.01% reduction and the paddy yield per plant of 24.97% and 51.35% under one week and two weeks water stress, respectively. On contrary, Basmati 2000 and Super Basmati were found to be the most sensitive to drought for paddy yield with 92.8% and 91.5% reduction under severe water stress given for two weeks, respectively. Rice strain 'IR55419-04' showed the potential for drought stress tolerance amongst all the tested genotypes (Sabar *et al.*, 2014).

Green Super Rice (GSR) cultivars are bred through an innovative introgression breeding strategy that requires less irrigation water and chemical inputs without compromising grain quality and yield. Five drought-tolerant GSR cultivars and two checks were subjected to continuously flooded (CF) and drought environments during the dry seasons of 2011 and 2012 at the International Rice Research Institute (IRRI) experimental farms in Philippines. All the cultivars performed satisfactorily in the CF environment with grain yield ranging from 5 to 11.5 tons ha⁻¹. Water stress during the reproductive stage significantly reduced grain yield by 75–88% in the moderate drought (soil water tension between 100 and 300 kPa in upper 15 cm soil layer) and 77–96% in the severe drought (soil water tension >300 kPa in upper 15 cm soil layer) experiments. Two GSR cultivars, GSR IR1-5-S10-D1-D1 and IR83142-B-19-B, responded well in severe drought environments, with grain yield almost similar to the drought check (1.79 tons ha⁻¹). Under moderate drought stress, there was a relative yield advantage of 25% and 40% for the two GSR cultivars over the drought check, respectively (Marcaida *et al.*, 2014).

There were large changes among NDVI (Normalized Difference Vegetative Index) values from tillering to filling stage of early and late rice, but they reached to 0.25 at heading and filling stage and did not change substantially. The grain yield of rice could be predicted more accurately by using NDVI at heading stage, and therefore, NDVI values ranging from 0.28–0.31 at heading stage can be considered enough to obtain more than 9 t ha⁻¹ rice grain yield (Wang Lin, 2014).

The objective of the study conducted by Dou *et al.*, (2015) was to determine the effects of water regime/soil condition (continuous flooding, saturated, and aerobic), cultivar ('Cocodrie' and 'Rondo') on rice grain yield, yield components and water productivity. Rice grain yield was significantly affected by the interaction between water regime and cultivar. Significantly higher yield was obtained in continuous flooding than in aerobic and saturated soil conditions but the latter treatments were comparable to each other. For Rondo, its grain yield has decreased with soil water regimes in the order of continuous flooding, saturated and aerobic treatments. Compared to aerobic condition, saturated and continuous flooding treatments had greater panicle number. The spikelet number of Cocodrie was 29% greater than that of Rondo, indicating that rice cultivar had greater effect

on spikelet number than water management. Water productivity was significantly affected by the interaction of water regime and cultivar. The results indicated that cultivar selection is most important factor in deciding what water management option to practice.

2.3 Interaction effect of different moisture regime and variety on the yield of the rice crop

The effect of soil moisture stress on growth and development of two upland rice cultivars (Brown gora, a traditional cv. and Vandana, an improved cultivar). The reduction was 67.3 and 40.3% in dry matter accumulation and 53.4 and 54.4% in leaf area at 40% water holding capacity as compared to 100% water holding capacity in Brown gora and Vandana, respectively at 35 days after stress imposition (Chauhan *et al.*, 1996).

Three upland rice (*Oryza sativa* L.) cultivars viz. CR 143-2-2, Annada and Cauvery, were grown in the field under three irrigation regimes. There was a significant reduction in grain yield in all the three rice cultivars with the decrease in irrigation regimes. Under higher moisture stress conditions, performance was best in CR 143-2-2 and poorest in Cauvery. At IWIPET = 0.5 the cultivar Cauvery did not flower at all. Flowering was delayed in all the cultivars with the decrease of irrigation regime (Pradhan *et al.*, 2003).

To identify drought tolerant rice variety, a pot experiment with three transplanted aman rice genotypes (Basmati, Binadhan4 and RD2585) was carried out by Zubaer *et al.* during July to December, 2006 to evaluate the effect of water stress at different growth stages of different transplanted aman rice genotypes. The experiment was conducted putting three rice genotypes at three water levels (100%, 70% and 40% FC). Plant height, numbers of tillers/hill, no. of filled grains /panicle, total dry matter/hill, 1000 grain weight, grain yield and harvest index were decreased with increasing water stress levels. Responses of the rice genotypes in different water stress varied significantly. There had been different degree of reduction to the yield contributing characters for the stress. Binadhan 4 performed better in producing tillers, leaves, total dry matter, and yield under stress than the other two genotypes. Basmati showed the highest plant height but

medium total dry matter, 1000 grain weight and yield. RD 2585 showed the lowest total dry matter, 1000 grain weight, and yield under water stress.

Sarvestani *et al.* (2008) conducted a field experiment to evaluate the effect of water stress on the yield and yield components of four rice cultivars commonly grown in Mazandaran province, Iran. The local and improved cultivars used were Tarom, Khazar, Fajr and Nemat. The different water stress conditions were water stress during vegetative, flowering and grain filling stages and well watered was the control. Water stress at vegetative stage significantly reduced plant height of all cultivars. Water stress at flowering stage had a greater grain yield reduction than water stress at other times. Water deficit during vegetative, flowering and grain filling stages reduced mean grain yield by 21, 50 and 21% on average in comparison to control respectively. The yield advantage of two semi dwarf varieties, Fajr and Nemat, were not maintained under drought stress. Total biomass, harvest index, plant height, filled grain, unfilled grain and 1000 grain weight were reduced under water stress in all cultivars. Water stress at vegetative stage effectively reduced total biomass.

The objectives of a study conducted by Abbasi *et al.* (2011) were to analyze the straw yield, grain yield, yield components, water use and water productivity (WP) of five rice cultivars (Anbarboo-22, Ghasroddashti, Cross-Domsiah, Hasani, and Rahmat-Abadi) under water saving irrigation regimes (intermittent flood irrigation with 1-and 2-day intervals after disappearance of standing water, I-1-D, and I-2-D, respectively) compared with continuous flood irrigation (CFI) to adopt the elite cultivars for these conditions. In general, Anbarboo-22 cultivar totally failed in field trial due to susceptibility to disease. Among the other cultivars, Cross-Domsiah showed the highest grain yield, harvest index, number of panicles per hill and the lowest unfilled grain percentage. Furthermore, its grain yield was the highest at water saving irrigation regimes in comparison with the other cultivars, therefore, Cross-Domsiah is the elite cultivar in water-saving irrigation conditions.

Fifteen rice genotypes were grown under irrigated and water stress conditions. Water stress was imposed at reproductive stage by withholding irrigation supply. The rice genotypes IR 83376-B-B-24-2, IR 83373-B-B-24-3 IR

84895-B-B-127-CRA-5-1-1 and IR83387-B-B-27-4 showed high yield potential. These drought tolerant genotypes were also superior in terms of grain yield and higher content of desired physio-morphological traits in terms of plant biomass (Santosh kumar *et al.*, 2014).

Sokoto *et al.* (2014) carried out a trial where the treatment consisted of water stress at three growth stages (tillering, flowering, grain filling) and no stress (control) and three rice varieties (FARO 44, NERICA 2 and FARO 15). The result indicated that water stress significantly resulted to decrease in plant height, number of leaves per plant, total biomass, harvest index and grain yield. FARO 44 differed significantly from NERICA 2 and FARO 15 at all the parameters under study.



MATERIALS AND METHODS

The field experiment on “Performance of non puddled transplanted summer rice cultivars under different moisture regimes” was conducted during summer season of 2015 in the Agronomy Main Research Farm, OUAT, Bhubaneswar. The details of the experimental materials used and the methodologies adopted during the process of field investigation and the related aspects are briefly described in this chapter.

3.1 Experimental site

The experiment was carried out during summer season of 2015 at Agronomy Main Research Farm, Department of Agronomy, College of Agriculture, Orissa University of Agriculture and Technology, Bhubaneswar, Odisha.

3.2 Location

The experimental site comes under the East and South-Eastern coastal plain agro-climatic zone of Odisha and situated at 20⁰ 15’ N latitude and 85⁰ 52’ E longitude at an elevation of 25.9 m above the mean sea level. It is located about 65 km west of the Bay of Bengal.

3.3 Soil characteristics

Soil samples were drawn from top 15 cm of soil layer randomly from different spots of the experimental site. A composite sample was prepared and analysed for various physico-chemical properties. The results are presented in Table 3.1 and 3.2. The soil of the experimental site was sandy loam.

Table 3.1 Mechanical composition of soil (0-15 cm)

Soil separate	Composition (%)	Method adopted
Sand	71.9%	Bouyoucos Hydrometer method Piper, 1950
Silt	11.5%	
Clay	16.6%	
Textural class	Sandy loam	

Table 3.2 Chemical composition of soil (0-15 cm)

Particular	Content	Method adopted
pH	5.8	pH meter method (Jackson,1967)
EC (dSm ⁻¹)	0.040	Digital electrical conductivity meter (Jackson,1967)
Organic carbon (%)	0.41	Walkley and Black's rapid titration method (Page <i>et al.</i> , 1982)
Available N (kg ha ⁻¹)	245.2	Alkaline Potassium Permanganate method (Subbiah and Asija, 1956)
Available P (kg ha ⁻¹)	43.4	Bray's-1 method (Jackson,1967)
Available K (kg ha ⁻¹)	166.8	Flame photo meter method (Jackson, 1967)

3.4 Season and climate

The Agronomy Main Research Farm, OUAT, Bhubaneswar is characterized by warm and moist climate with hot and humid summer and mild winter. Broadly, the climate falls under the group of moist hot type. Nearly 76% of the annual rainfall is received between June to September. The rainfall is monsoonal and unimodal. The South-West monsoon in Odisha usually sets in around mid-June and recedes by mid-October.

The data regarding different weather parameters recorded at the meteorological observatory at Agronomy Main Research Farm, OUAT during the period of experimentation are presented in Table 3.3 and 3.4.

3.4.1 Rainfall and rainy days

The mean annual rainfall of Bhubaneswar is 1408.4 mm (1985-2014). South West monsoon sets by 10 June and recedes by 15 October. The distribution of rainfall is uneven and nearly 88% of the total annual rainfall is received during the period from June to October. April and May are relatively dry months.

Rainfall received during different months of cropping season under report were 10.75 mm in January, 18.4 mm in February, 8.3 mm in March, 19.3 mm in April, 5.48 mm in May, 180.5 mm in June as against the preceding 30 years average of 12.4 mm in January, 24.3 mm in February, 22.1 mm in March, 28 mm in April, 60.7 mm in May, 196.2 mm in June. Thus the total rainfall during the season of experiment (January to June 2015) was 100.97 mm less than that of 30 years average up to June i.e. up to harvest of the rice crop. The entire cropping season was drier than the normal.

3.4.2 Pan evaporation

Evaporation loss from the USDA, Class A open pan evaporimeter increased gradually with increasing temperature reaching the maximum in the month of May. The mean evaporation during the cropping season (January to June 2015) was 5.08 mm day⁻¹.

3.4.3 Atmospheric temperature

Data on air temperature during the experimental period along with deviation from normal are given in Table . Mean maximum and minimum temperature during the cropping season were, respectively 27.8 °C and 14.2 °C in January, 32.5 °C and 17 °C in February, 35.8 °C and 21.5 °C in March, 37.1 °C and 24.2 °C in April, 38.97°C and 27.03°C in May, 35.9°C and 26.4°C in June as against the 30 years normal temperature of 29.2°C and 15.5°C in January, 31.8 °C and 18.7°C in February, 34.9°C and 22.5 °C in March, 36.6°C and 25 °C in April, 37.4°C and 26.4 °C in May, 35.1°C and 26.3 °C in June.

3.4.4 Wind velocity

The average wind velocity during the cropping season from January 2015 to June 2015 were 2.9, 3.2, 4.5, 7.5, 8.1 and 8.7 km h⁻¹, respectively as against normal wind velocity 7.3, 9.1, 12.8, 19.1, 18.8 and 14.7 km h⁻¹. The atmosphere was less windy than the normal.

3.4.5 Bright sunshine hours (BSH)

The average BSH per day from January to June for last 30 years were 7.7, 8.3, 8.2, 8.5, 8.5 and 4.9 hours day⁻¹ respectively. In the cropping season the corresponding values were 6.7, 8.3, 8.0, 7.2, 8.1 and 5.2 hours day⁻¹ with the average of 7.3 hours day⁻¹.

3.4.6 Relative Humidity (RH)

The mean monthly relative humidity percentage values during morning and afternoon were 91% and 43%, 94% and 39%, 91% and 40%, 88% and 50%, 87.8% and 51.1%, 89% and 63% from January 2015 to June 2015, respectively. The last 30 years average RH values were 71% and 50%, 72% and 50%, 72% and 53%, 70% and 60%, 70% and 61% and 76% and 70 % from January to June respectively.

Table 3.3 Mean weekly weather data during crop growing season

SMW	Date	Rainfall (mm)	Evaporation (Mm/Day)	Atm. Temp . (°C)		Relative Humidity (%)		Bsh (Hour/Day)	Wind Velocity (km/hr.)
				Max.	Min.	Fn	An		
3	15 Jan-21 Jan	0	3.47	25.67	11.81	86.71	32.42	7.67	2.58
4	22 Jan-28 Jan	0	3.52	29.64	13.48	93.85	41.00	7.48	1.70
5	29 Jan-04 Feb	0	3.64	29.12	14.5	89.57	41.00	7.74	2.41
6	05 Feb- 11 Feb	0	3.75	31.28	15.17	93.42	36.28	6.97	1.85
7	12 Feb-18 Feb	2.62	3.92	31.8	17.4	94.57	47.85	7.84	3.24
8	19 Feb- 25 Feb	0	4.10	35.18	19.27	94.00	35.28	9.25	4.12
9	26 Feb- 04 Mar	0.4	4.52	35.68	22.62	90.71	37.71	8.55	4.71
10	05 Mar-11 Mar	0	5.92	34.68	19.81	90.28	32.85	8.48	2.88
11	12 Mar- 18 Mar	0	6.41	36.55	21.12	89.14	34.71	7.97	4.00
12	19 Mar- 25 Mar	2.77	6.32	36.34	23.18	94.71	42.42	8.54	4.14
13	26 Mar- 01 Apr	0.371	6.28	36.14	22.91	91.28	49.00	6.94	7.32
14	02 Apr- 08 Apr	3.74	6.78	37.51	25.08	90.85	58.00	6.78	9.57
15	09 Apr-15 Apr	0.45	6.31	35.9	23.35	88.28	46.42	5.41	4.70
16	16 Apr-22 Apr	0.54	7.10	38.35	24.75	84.28	46.00	8.38	8.37
17	23 Apr- 29 Apr	11.8	6.20	36.84	23.45	89.00	49.71	8.41	7.75
18	30 Apr- 06 May	0	8.04	36.55	26.7	88.57	57.71	8.31	7.25
19	07 May- 13 May	3.11	8.54	38.15	26.18	88.85	52.71	7.41	7.27
20	14 May- 20 May	0.4	8.95	38.55	26.54	86.71	50.85	8.84	7.25
21	21 May-27 May	0.4	9.58	42.02	29.05	89.71	43.71	7.72	7.98
22	28 May-03 June	3.85	9.78	42.86	30.25	90.02	45.00	7.52	7.13
23	04 June-10 June	4.2	9.68	43.2	31.75	90.3	45.40	8.4	7.32

Table 3.4 Current, normal and deviation in weather data for cropping season (January to June 2015)

MONTH	Particulars	Rainfall (mm)	Relative Humidity (%)			BSH (hrs/day)	Temperature (°C)			Wind Velocity (km/hr)
			Morn.	AN	Mean		Max.	Min.	Mean	
January	Current	10.75	91	43	67	6.7	27.8	14.2	21	2.9
	Normal	12.4	71	50	60.5	7.7	29.2	15.5	22.35	7.3
	Deviation	-1.65	20	-7	6.5	-1	-1.4	-1.3	-1.35	-4.4
February	Current	18.4	94	39	66.5	8.3	32.5	17	24.75	3.2
	Normal	24.3	72	50	61	8.3	31.8	18.7	25.25	9.1
	Deviation	-5.9	22	-11	5.5	0	0.7	-1.7	-0.5	-5.9
March	Current	8.3	91	40	65.5	8	35.8	21.5	28.65	4.5
	Normal	22.1	72	53	62.5	8.2	34.9	22.5	28.7	12.8
	Deviation	-13.8	19	-13	3	-0.2	0.9	-1	-0.05	-8.3
April	Current	19.3	88	50	69	7.2	37.1	24.2	30.65	7.2
	Normal	28	70	60	65	8.5	36.6	25	30.8	19.1
	Deviation	-8.7	18	-10	4	-1.3	0.5	-0.8	-0.15	-11.9
May	Current	5.48	87.8	51.1	69.45	8.13	38.97	27.03	33	8.1
	Normal	60.7	70	61	65.5	8.5	37.4	26.4	31.9	18.8
	Deviation	-55.22	17.8	-9.9	3.95	-0.37	1.57	0.63	1.1	-10.7
June	Current	180.5	89	63	76	5.2	35.9	26.4	31.15	8.7
	Normal	196.2	76	70	73	4.9	35.1	26.3	30.7	14.7
	Deviation	-15.7	13	-7	3	0.3	0.8	0.1	0.45	-6

Table 3.6 Details of the experiment

Design	Alpha lattice design
Number of treatments	Factor 1- Cultivars (24) Factor 2- Moisture regimes (2)
Number of replications	3
Number of plots	144
Plot size	4 m x 2.07 m

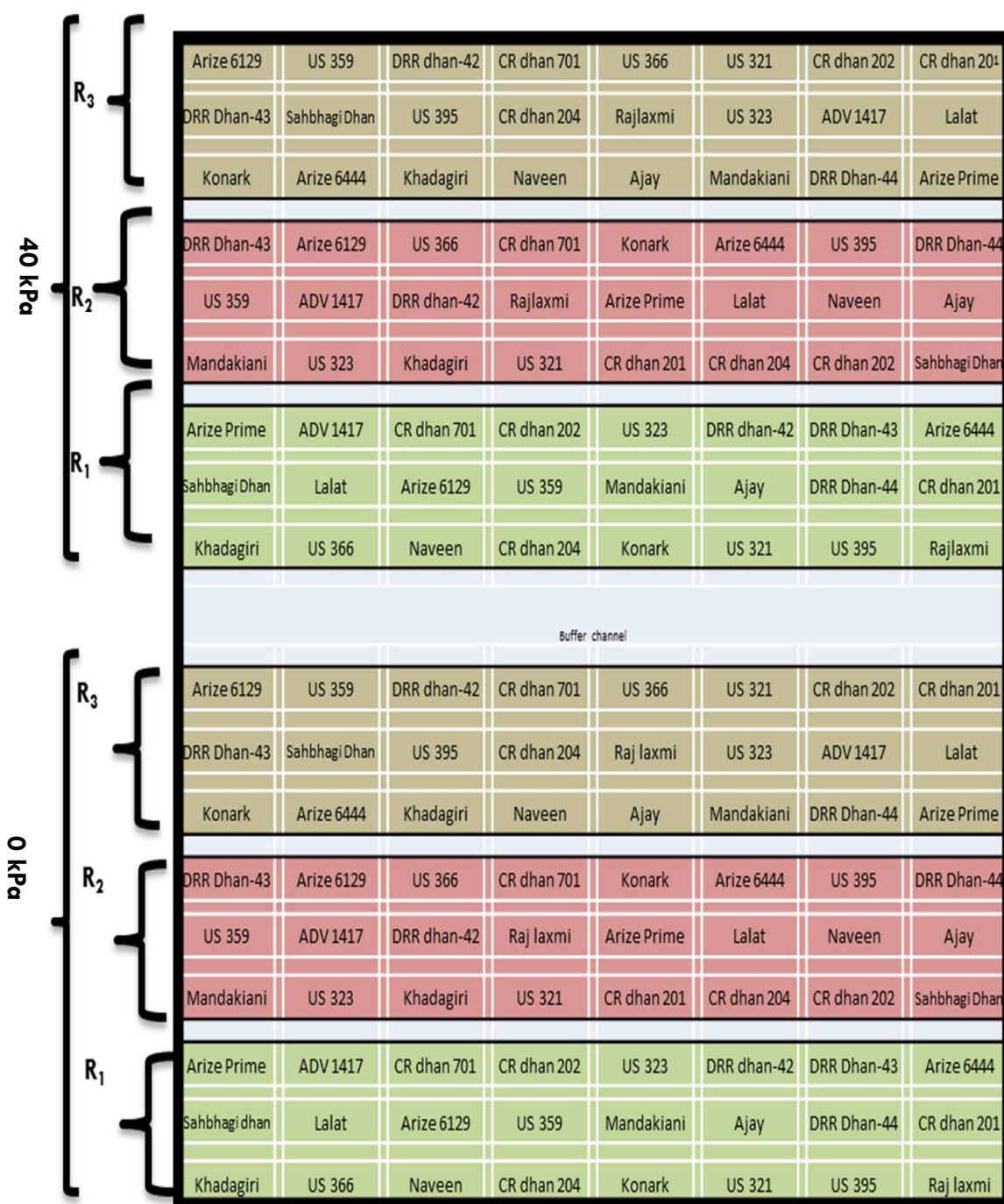


Fig. 3.1 Layout plan of experimental field

3.7 Rice cultivars

3.7.1 Sahabhagi dhan (IR 74371-70-1-1-CRR-1)

It is an early maturing (100 days), semi-dwarf statured (85-90 cm) variety, released from National Rice Research Institute, Cuttack and notified during 2008 and 2011, respectively for cultivation in the states of Jharkhand and Odisha. This is a variety with tolerance to drought stress and responsive to favourable conditions. It is suitable for upland, rainfed direct seeded as well as transplanted conditions. It bears golden husked long bold grains. Its average productivity ranges from 3.8 tonnes ha⁻¹ to 4.5 tonnes ha⁻¹. An yield advantage of 0.5 tonnes ha⁻¹ under moderate drought stress and 1.0 tonnes ha⁻¹ under severe drought conditions, over IR 64 and IR 36, has been recorded by this variety. It is resistant to leaf blast and moderately resistant to brown spot, sheath rot, stem borer and leaf folder.

3.7.2 Mandakini (OR 2077-4)

It is a semi-dwarf statured non-lodging variety with early maturity (100 days) developed by Orissa University of Agriculture and Technology (OUAT). It is suitable for late sown conditions and was released in 2010. It possesses medium slender grains, dull red kernel, straw colour hull, stout stem and profuse tillering habit. It is resistant to blast, sheath blight, gall midge, leaf folder, whorl maggot and moderately resistant to sheath rot, rice tungro virus. The average productivity is 3.72 tonnes ha⁻¹.

3.7.3 Khandagiri (IET-10396)

The variety was developed from the parentage of Parijat X IR-13429-94-3-2-2 and was released by Orissa University of Agriculture and Technology (OUAT) and notified in the year 1994. The variety has a duration of 90-95 days and is suitable for rainfed and irrigated uplands. It possesses white medium slender grains. It is resistant to sheath rot, neck blast, brown spot, brown plant hopper and moderately resistant to rice tungro virus, sheath blight, bacterial leaf blight, gall midge and whorl maggot. The average productivity is 3.5 tonnes ha⁻¹.

3.7.4 ADV 1417

It is a variety of the private sector company named Advanta. The duration of the variety is 100 days and is suitable for upland and irrigated ecosystems of Odisha,

West Bengal, Tripura and Andhra Pradesh. This variety has resistance against blast and brown spot. The average productivity is 4 tonnes ha⁻¹.

3.7.5 DRR Dhan 42

The variety has been developed and released by the Directorate of Rice Research, Hyderabad. It is a semi-dwarf statured non-lodging variety with early maturity (100 days). It is resistant to blast and moderately resistant to rice tungro virus. It also shows field tolerance against bacterial leaf blight, stem borer and brown plant hopper. The average productivity is 4 tonnes ha⁻¹.

3.7.6 DRR Dhan 43

The variety has been developed and released by the Directorate of Rice Research, Hyderabad and has a duration of 100 days. It possesses short bold grains with an average productivity of 4.5 tonnes ha⁻¹. It exhibits tolerance to stem borer, brown plant hopper, white backed plant hopper, gall midge, leaf blast and bacterial leaf blight.

3.7.7 US- 321

The variety has been developed by US Agri seeds, which is a private sector enterprise. It is a hybrid variety with a duration from 90-100 days and has an average productivity of 4.5 tonnes ha⁻¹. However, the variety is susceptible to brown spot and gall midge.

3.7.8 US-323

The variety is released and marketed by US Agri seeds. It is a dwarf statured non-lodging hybrid variety with early maturity of around 100 days. It shows tolerance to drought stress and responsive to favourable conditions. It is suitable for upland, rainfed direct seeded as well as transplanted conditions. It bears bold grains and has an average productivity of 4.5 tonnes ha⁻¹.

3.7.9 US-359

The variety has an early duration of around 100 days with an average productivity of 4.5 tonnes ha⁻¹ when grown under appropriate cultural practices and good management. It is a hybrid variety so responsive to inputs and is resistant to brown spot disease.

3.7.10 Naveen (CR 749-20-2)

It is a mid-early duration (115-120 days), semi-dwarf (105 cm) variety suitable for upland and irrigated ecosystems. It is released and notified in 2005 and 2006, respectively for cultivation in Odisha, West Bengal, Tripura and Andhra Pradesh. It has medium bold grains with average productivity of 4.0-5.0 tonnes ha⁻¹ in kharif and 5.0-6.0 tonnes ha⁻¹ in rabi season. This variety has resistance against blast and brown spot.

3.7.11 Konark (IET 1009)

It was notified in the year 1999. The duration of the variety is 120 days and is suitable for irrigated ecosystem in medium land, has a semi-dwarf stature and the grains are white in colour. The variety is tolerant to brown plant hopper and is suitable for cultivation in Odisha. The average productivity is 5 tonnes ha⁻¹.

3.7.12 CR Dhan 201 (CR 2721-81-3-IR 83380-B-B124-1)

It is a mid early duration (110-115 days), semi-dwarf, non-lodging variety suitable for water limited/ aerobic conditions, released from National Rice Research Institute, Cuttack and notified (2012 and 2014, respectively) for cultivation in Bihar and Chattisgarh. It possesses long slender grains with average productivity of 3.8 tonnes ha⁻¹. The genotype is having more panicles per metre square (280) with long and dense panicles and moderate test weight. It is moderately resistant to leaf blast, sheath rot, stem borer (both dead heart and white ear heads), leaf folder, whorl maggot and rice thrips.

3.7.13 CR Dhan 202 (CR 2715-13-IR 84899-B-154)

It is a semi-dwarf statured mid early duration (110 days) variety, suitable for water limited or aerobic conditions and released by National Rice Research Institute, Cuttack and notified (2012 and 2014, respectively) for cultivation in Jharkhand and Odisha. It possesses short bold grains with an average productivity of 3.7 tonnes ha⁻¹. It has higher number of panicles per metre square (285), normal tillering (7-10), medium and dense panicles with moderate test weight. It is moderately resistant to leaf blast, brown spot, sheath rot, stem borer (both dead heart and white ear heads), leaf folder, whorl maggot and rice thrips.

3.7.14 CR Dhan 204 (CR 2715-13-IR 84899-B-154)

It is a semi-dwarf statured non-lodging variety with mid early maturity duration (110 days) . It is suitable for water limited or aerobic conditions and released

from National Rice Research Institute, Cuttack and notified (2012 and 2014 respectively) for cultivation in Jharkhand and Tamil Nadu. It possesses medium slender grains, higher number of panicles per metre square (285) with average yield of 3.9 tonnes ha⁻¹. It is moderately resistant to leaf blast, neck blast, brown spot, sheath rot, stem borer (both dead heart and white ear heads), leaf folder, whorl maggot, case worm and rice thrips.

3.7.15 Arize 6129

The variety has been developed by Bayer Crop Science, a private sector enterprise. India's first bacteria leaf blight resistant short duration hybrid. It consistently gives high yield of 20-25% more than the other high yielding varieties of same duration. It is an early duration hybrid (115-120 days) with maximum productive tillers, high grain filling > 90% & more grain per panicle (275-300), less water requirement & wider adaptability. It fits well in vegetable or potato and wheat crop rotations

3.7.16 Ajay (CRHR-7)

It is a medium duration (125-135 days), semi-dwarf (105-110 cm) popular hybrid variety developed by National Rice Research Institute, Cuttack released and notified (2005 and 2006, respectively) for cultivation under irrigated and shallow lowland areas of Odisha. It has good quality long slender grains with an average yield of 7.0-7.5 tonnes ha⁻¹. It is resistant to blast and moderately resistant to rice tungro virus. It also shows field tolerance against bacterial leaf blight, stem borer and brown plant hopper. It can tolerate water stagnation (7-10 days) at tillering stage.

3.7.17 Rajlaxmi (CRHR-5)

It is a medium duration (125-135 days), semi-dwarf (105-110 cm) popular hybrid variety developed by National Rice Research Institute, Cuttack. It possesses seedling stage cold tolerance and suitable for irrigated and boro ecosystems. It is released (2005 SVRC; 2010 CVRC) and notified (2006) for cultivation in Odisha and Assam. It has good quality long slender grains with an average productivity of 7.0-7.5 tonnes ha⁻¹. It has capability to tolerate stem borer, brown plant hopper, white backed plant hopper, gall midge, leaf blast and bacterial leaf blight. This hybrid can tolerate water stagnation (7-10 days) at tillering stage.

3.7.18 Lalat (IET-9947)

It has been developed from IR-207 X Vikram. It was notified in the year 1989 and has a duration of 125-130 days. It is suitable for irrigated medium lands. It is dwarf in height (85-90 cm), grains are long and slender. The variety is resistant to blast, sheath blight, brown spot, rice tungro virus, bacterial leaf blight and has an average productivity of 4 tonnes ha⁻¹.

3.7.19 US- 366

It is an hybrid variety of 125-135 days duration developed by US Agri seeds. It is suitable for irrigated medium lands. The average productivity is 6.5 tonnes ha⁻¹. However the variety is susceptible to bacterial leaf blight and brown spot.

3.7.20 US-395

It is one of the well performing varieties among the cluster of 125-135 days duration cultivar. The variety is tolerant to drought situations and has a higher harvest index. It is resistant to bacterial leaf blight.

3.7.21 DRR Dhan 44

The variety has been released from the Directorate of Rice Research, Hyderabad and has a duration of 125-135 days. It has medium slender grains with average productivity of 6.0 tonnes ha⁻¹. It is suitable for irrigated medium lands. It has capability to tolerate stem borer, brown plant hopper, white backed plant hopper, gall midge, leaf blast and bacterial leaf blight.

3.7.22 CR Dhan 701 (CRHR-32)

It is the first late duration (142-145 days) hybrid variety in India, released from National Rice Research Institute, Cuttack and notified (2010 and 2012, respectively) for cultivation in shallow lowland areas of Bihar and Gujarat. It has medium slender grains with average productivity of 6.0-6.5 tonnes ha⁻¹. It can withstand water logging and low light conditions. It shows moderate resistance to rice tungro virus, bacterial leaf blight, green leaf hopper and leaf blast. It can also be cultivated during dry season if sown in December.

3.7.23 Arize 6444

This hybrid variety has been developed by Bayer Crop Science. It is resistant to bacterial leaf blight and consistently yields 25-30% higher than popular inbred

varieties. It has a medium duration (135-140 days), higher number of productive tillers per plant (12-15), wider adaptability, more than 70% milling, suitable for direct seeded rice system and has been notified by Government of India.

3.7.24 Arize prima

This hybrid variety has been developed by Bayer Crop Science. It produces yield (25% -30% more than inbred Varieties). It has a duration (approx 135-140 days), medium slender grain, more productive tillers per plant and has been notified by Government of India.

3.8 Details of field operation

3.8.1 Mat nursery preparaion

Mat nursery was prepared by cutting the polythene sheets in accordance to the dimension of the frame which was to be used. The dimensions of the frame was 2 m X 1.20 m. The soil was placed in it along with DAP (18-46-0) and vermicompost. The pre-soaked seeds were spread on the soil and was covered with the mixture of vermicompost and fine sieved soil. Water was applied with the help of a rose can and was covered with mulch. The mat nursery was prepared on 15.01.2015.

3.8.2 Land preparation

The experimental area was ploughed thrice. The first ploughing was done by tractor while the second and third ploughings were done by harrows. Weeds were removed from the plot by raking and it was leveled with the help of a laser leveller. The experimental area was divided into plots of dimensions 4 m X 2.07 m. A buffer channel was made in order to separate the 0kPa block from the 40 kPa block.

3.8.3 Transplanting

The transplanting was done on 09.02.15 in the 0 kPa moisture regime and on 10.02.15 in the 40 kPa moisture regime and the cultivars were transplanted in the respective plots as per lay out of the experimental design.

3.8.4 Fertilizer management

Well decomposed FYM @5t ha⁻¹ was incorporated into the soil at final ploughing. Inorganic fertilizers @ 80-40-40 kg N, P₂O₅, K₂O ha⁻¹ were applied to all the plots. Full dose of P and K and 25% of N was applied at final ploughing. Rest of N was applied in 2:1 ratio at tillering and panicle initiation stage, respectively.

3.8.5 Interculture and plant protection

Butachlor @ 1 kg ha⁻¹ was applied as pre emergence following the day after transplanting of crop . Monocrotophos @ 1.25l ha⁻¹ was applied to manage insect population and Chloropyriphos @ 10 kg ha⁻¹ was dusted to check termite attack.

3.8.6 Irrigation

Crop was irrigated as and when soil developed moisture stress. The 0 kPa block was irrigated when there was disappearance of the ponded water and the 40 kPa block was irrigated when the tensiometers that were installed read 40 kPa. No irrigation was given 10 days before harvest of the crop.

3.8.7 Harvesting and threshing

Harvesting was done when the crop attained physiological maturity. The grains were separated by threshing, and along with straw were sun dried. The grain and straw yield per net plot was recorded and reported as per ha

Table 3.7 Calendar of field operations undertaken during the period of study

Sl. No.	Particulars	0 Kpa	40Kpa
1	Mat nursery preparation	15.01.2015	15.01.2015
2	Levelling	06.02.2015	06.02.2015
3	Layout	07.02.2015	07.02.2015
4	Transplanting	09.02.2015	10.02.2015
5	Fertiliser application (Basal)	09.02.2015	10.02.2015
6	1 st Top dressing	25.02.2015-07.03.2015	23.02.2015-01.03.2015
7	2 nd Top dressing	16.03.2015-03.04.2015	13.03.2015-01.04.2015
8	Number of irrigation	Depending on the disappearance of ponded water	Depending on the reading of the tensiometer installed
a.	Early cultivars	12	8
b.	Mid-early cultivars	14	10
c.	Medium cultivars	16	12
d.	Late cultivars	18	14
9	Harvesting		
a.	Early cultivars	19.04.2015-24.04.2015	10.04.2015-24.04.2015
b.	Mid-early cultivars	02.05.2015-10.05.2015	23.04.2015-01.05.2015
c.	Medium cultivars	24.05.2015-28.05.2015	01.05.2015-24.05.2015
d.	Late cultivars	31.05.2015-05.06.2015	28.05.2015-03.06.2015
10	Threshing		
a.	Early cultivars	23.04.2015-28.04.2015	14.04.2015-28.04.2015
b.	Mid-early cultivars	05.05.2015-14.05.2015	27.04.2015-05.05.2015
c.	Medium cultivars	29.05.2015-01.06.2015	05.05.2015-29.05.2015
d.	Late cultivars	04.06.2015-10.06.2015	01.06.2015-07.06.2015

3.9 Collection of experimental data

No monitoring for any parameters in the first three border rows and 0.5 m from width side. The growth and yield parameters were recorded at regular intervals of 15 days after sowing and at harvest. Yield was recorded on net plot basis.

The procedure followed for measuring various growth and yield parameters are given below:

3.9.1 Pre harvest studies

3.9.1.1 Total number of tillers

Total tillers m^{-2} was recorded from each plot at every 15 days interval till the harvest. The mean value was computed and expressed.

3.9.1.2 Leaf area index (LAI)

Five permanent rows were selected for reading. The reading was taken by putting Accu PAR probe between the rows just above the ground. The reference probe was above the canopy, straight and at particular area. The reading was taken in between 9 a.m to 3 p.m.

3.9.1.3 Canopy temperature

Infrared thermometers were used for measuring ambient and canopy temperature. The differential between ambient air temperature and leaf temperature (ΔT) is a great indicator of a crops stress, especially from lack of irrigation water and the subsequent yields. The infrared thermometer provides a simple, fast and accurate means of testing the differential temperature (ΔT). The following precautions need to be taken while measuring the canopy temperature like plant leaf surface must be dry, to be used only when wind is blowing at less than 10 metres per hour, the sunlight should be kept at back, readings are taken from foliage only during the peak sunlit hours of the day, when stress is most likely to occur. Therefore, readings are taken from 11 AM to 4 PM during the summer and from 1 PM to 3 PM during the winter. The magnitude of the temperature difference between the canopy and the ambient temperature is a measure of the stress level of the plants.

3.9.1.4 Normalized difference vegetative index

The reading or the NDVI value is obtained by the help of an instrument named green seeker. It measures the health or the vigour of the crop. Higher is the reading , healthier is the plant. The index varies from 0.00-0.99. The index obtained on the green seeker is the ratio of

$$\text{NDVI} = \frac{\text{NIR-RED}}{\text{NIR+RED}}$$

where, NIR- Near Infrared

RED- Red band light of visible spectrum

3.9.1.5 Phenology of crop

Crop phenology was determined as the length of time from planting to maximum tillering, flower primordial initiation (PI), ear head emergence, flowering, milk, dough and physiological maturity. Four hills from each plot were selected randomly for periodic observation on phenological stages. When all plants attained a particular stage, the day was considered as the date for attainment of that stage. The vegetative phase is defined as the period from transplanting to flower primordial initiation and reproductive phase as period from flower primordial to maturity.

3.9.1.6 Computation of Growing Degree Days

The growing degree days or heat unit requirement of rice crop is determined by formula:

$$\text{Growing degree days (GDD)} = \sum \left[\left(\frac{T_{\max} + T_{\min}}{2} \right) - T_b \right]$$

T_{\max} and T_{\min} are daily maximum and minimum temperatures and T_b is the base temperature, temperature below which there is no crop growth. Hence, T_b is minimum threshold (base), is crop specific and for rice it is 10^0 C (Gao and Jin,1992).

3.9.2 Parameters at harvest and post harvest

The yield attributing characters like panicle length, number of filled grains panicle⁻¹, spikelet fertility percentage, 1000 grain weight, grain yield, straw yield, harvest index were recorded from net plot area after the harvest of the rice crop.

3.9.2.1 Panicle length (cm)

Panicle length from ten randomly selected panicles in each plot from all replications was recorded from base of the panicle to tip of the top most spikelet. The mean of panicle length was computed and expressed in centimetre.

3.9.2.2 Number of filled grains per panicle

From the ten randomly selected panicles filled grains were counted and averaged to obtain the number of filled grains panicle⁻¹.

3.9.2.3 Spikelet fertility percentage

It was worked out from the number of fertile filled and sterile spikelets (unfilled /chaff) panicle⁻¹ by using the formula.

$$\text{Spikelet fertility percent} = \frac{\text{No. of fertile spikelets per panicle}}{\text{Total number of spikelets per panicle}} \times 100$$

3.9.2.4 Test weight (g)

One thousand bold grains (filled spikelet) were counted from the produce of the net plot of each treatment. The weight of grains was recorded and expressed as test weight in grams.

3.9.2.5 Grain yield (t ha⁻¹)

Grains from corresponding net plots were threshed, winnowed, sundried and weighed. It was converted to t ha⁻¹ and reported at 14% moisture level.

3.9.2.6 Straw yield (t ha⁻¹)

Straw yield from corresponding net plots was sundried and weighted and reported in t ha⁻¹.

3.9.2.7 Harvest index (HI)

Harvest index is the ratio of the grain weight to the total plant weight (excluding roots) and is expressed on percent basis. It was computed as per the following formula.

$$\text{HI} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

Where economic yield is the grain yield ($t\ ha^{-1}$) and biological yield is the total above ground biomass (grain + straw) yield in $t\ ha^{-1}$.

3.10 Water requirement and water use efficiency

Water requirement was calculated taking irrigation applied into consideration. Water use efficiency of rice crop was estimated from the data on grain yield and water requirement and expressed as $kg\ ha^{-1}cm$.

3.11 Statistical analysis

The experimental data were subjected to analysis by adopting incomplete block design (Alpha lattice) method of analysis of variance to draw a valid conclusion. The variations in the treatment mean were tested by using critical difference (CD) values at 5 percent level of significance .

3.12 Economics

The economics for different cultivars in different moisture regimes was worked out on per hectare basis taking into consideration the market value of the inputs, produce and that of by product (straw) obtained. Net return (₹ per hectare) and benefit: cost ratio was worked out.

$$\text{Net return} = \text{Gross return (₹)} - \text{Cost of cultivation (₹)}$$

$$\text{Benefit-cost ratio} = \frac{\text{Gross return (₹)}}{\text{Total cost of cultivation (₹)}}$$



EXPERIMENTAL RESULTS

In this chapter an endeavor has been made to study the performance of the non puddled transplanted summer rice cultivars under different moisture regimes on specified emphasis to the behavioural response of rice phenology , growth and yield of summer rice cultivars under different moisture regimes. The irrigation water applied has also been studied. Observations on different parameters recorded during the course of investigation were analysed statistically and the results have been presented here.

4.1 Performance of non-puddled transplanted summer rice cultivars under different moisture regimes

4.1.1 Pre-harvest studies

4.1.1.1 Crop phenology study

Phenology of crop in terms of occurrence of different stages attained after the days of sowing are recorded and presented in Table 4.1 and 4.2.

Data revealed that the number of calendar days required for the physiological maturity of the cultivars Shahabhagi and US 323 among the early group, CR Dhan 202 among the group of mid early cultivars, US-395 amidst the medium cultivars and Arize 6444 in the section of mid late cultivars was 100, 100, 108,132 and 143 days, respectively in the 0 kPa moisture regime. In these cultivars hardly any differences observed (0-3 days) for attaining physiological maturity even under 40 kPa moisture regime. Whereas, a difference of almost 8 to 21 days was noted for attaining physiological maturity in rest of the varieties when grown under moisture stress condition (40 kPa).

Table 4.1 Phenology of different summer rice cultivars and their GDD requirement under 0 kPa moisture regime

Variety	Emergence	GDD	MT	GDD	PI	GDD	50 % flowering	GDD	PM	GDD	Duration
Shahabhazi	3	30.1	41	522.55	45	594.9	71	1085.35	100	1683.9	100 days
Mandakini	3	30.1	44	577.3	46	611.4	70	1065.35	98	1639.45	98 days
Khandagiri	3	30.1	43	558.6	45	594.9	69	1044.45	95	1571.75	95 days
ADV 1417	3	30.1	45	594.9	49	674.35	73	1124.45	100	1683.9	100 days
DRR Dhan 42	3	30.1	44	577.3	48	655.4	72	1104.65	99	1661.65	99 days
DRR Dhan 43	3	30.1	47	636.7	51	708.3	77	1202.5	100	1683.9	100 days
US 321	3	30.1	47	636.7	49	674.35	71	1085.35	100	1683.9	100 days
US 323	3	30.1	50	692.35	54	759.1	70	1065.35	100	1683.9	100 days
US 359	3	30.1	47	636.7	49	674.35	73	1124.45	100	1683.9	100 days
Naveen	3	30.1	52	725.4	57	813	83	1331	114	1972.1	114 days
Konark	3	30.1	52	725.4	57	813	85	1370.75	116	2018.8	116 days
CR Dhan 201	3	30.1	53	742	58	832.2	84	1351.15	110	1883.75	110 days
CR Dhan 202	3	30.1	48	655.4	54	759.1	80	1267.85	108	1841.55	108 days
CR Dhan 204	3	30.1	54	759.1	59	850.5	86	1391.5	115	1995.7	115 days
Arize 6129	4	35.1	61	890.4	71	1085.35	100	1683.9	129	2314.75	129 days
Ajay	4	35.1	63	927	73	1124.45	106	1800.4	132	2394.4	132 days
Rajlaxmi	4	35.1	61	890.4	71	1085.35	100	1683.9	130	2340.6	130 days
Lalat	4	35.1	65	962.6	75	1161.55	104	1762.1	131	2367.2	131 days
US 366	5	44	63	927	73	1124.45	102	1724.1	130	2340.6	130 days
US 395	5	44	65	962.6	75	1161.55	104	1762.1	132	2394.4	132 days
DRR Dhan 44	5	44	69	1044.45	79	1245.35	108	1841.55	134	2442.25	134 days
CR DHAN 701	7	61.2	74	1141.55	89	1451.45	117	2039.6	145	2699.25	145 days
Arize 6444	7	61.2	76	1181.15	88	1433.65	115	1995.7	143	2652.95	143 days
Arize Prima	7	61.2	74	1141.55	79	1245.35	108	1841.55	137	2513.55	137 days

MT- Maximum Tillering, **PI-** Panicle Initiation, **PM-** Physiological Maturity, **GDD-**Growing Degree Days

Table 4.2 Phenology of different summer rice cultivars and their GDD requirement under 40 kPa moisture regime

VARIETY	Emergence	GDD	MT	GDD	PI	GDD	50% flowering	GDD	PM	GDD	Duration
Shahabhagi	3	30.1	41	522.55	45	594.9	71	1085.35	98	1639.45	98 days
Mandakini	3	30.1	39	488.35	43	558.6	65	962.6	90	1469.25	90 days
Khandagiri	3	30.1	34	402.85	38	472.05	60	983	86	1391.5	86 days
ADV 1417	3	30.1	40	505.35	42	540.25	66	983	90	1469.25	90 days
DRR Dhan 42	3	30.1	40	505.35	44	577.3	65	962.6	88	1433.65	88 days
DRR Dhan 43	3	30.1	43	558.6	45	594.9	68	1023.3	89	1451.45	89 days
US 321	3	30.1	37	454.75	41	522.55	61	890.4	88	1433.65	88 days
US 323	3	30.1	50	692.35	54	759.1	70	1065.35	100	1683.9	100 days
US 359	3	30.1	38	472.05	41	522.55	65	962.6	91	1488.55	91 days
Naveen	3	30.1	44	577.3	49	674.35	76	1181.15	103	1742.4	103 days
Konark	3	30.1	38	472.05	44	577.3	73	1124.45	100	1683.9	100 days
CR Dhan 201	3	30.1	44	577.3	50	692.35	74	1141.55	99	1661.65	99 days
CR Dhan 202	3	30.1	49	674.35	54	759.1	80	1267.85	107	1820.6	107 days
CR Dhan 204	3	30.1	42	540.25	48	655.4	73	1124.45	102	1724.1	102 days
Arize 6129	4	35.1	44	577.3	54	759.1	82	1309.8	110	1883.75	110 days
Ajay	4	35.1	49	674.35	59	850.5	85	1370.75	112	1926.9	112 days
Rajlaxmi	4	35.1	50	692.35	60	983	86	1391.5	112	1926.9	112 days
Lalat	4	35.1	45	594.9	55	776.4	83	1331	110	1883.75	110 days
US 366	5	44	54	759.1	64	945.1	92	1508.05	116	2018.8	116days
US 395	5	44	63	927	73	1124.45	102	1724.1	130	2340.6	130 days
DRR Dhan 44	5	44	54	759.1	64	945.1	92	1508.05	121	2125.9	121 days
CR DHAN 701	7	61.2	62	907.4	77	1202.05	105	1780.5	133	2418.75	133 days
Arize 6444	7	61.2	74	1141.55	86	1391.5	113	1949.1	140	2584.2	140 days
Arize Prima	7	61.2	51	708.3	63	927	91	1488.55	120	2103.1	120 days

MT- Maximum Tillering, **PI-** Panicle Initiation, **PM-** Physiological Maturity, **GDD-**Growing Degree Days

4.1.1.2 Total number of tillers

Tiller count of the various cultivars as influenced by the differential moisture regime are recorded in the Table 4.3.

Total tiller m^{-2} increased with age of the plant up to 45 days after sowing in early duration cultivars, 60 days after sowing in mid early duration cultivars, 75 days after sowing in medium and mid late duration cultivars.

Higher number of tiller m^{-2} was reported from Shahabhazi and US-323 among the early duration cultivars, CR Dhan 202 among the mid early duration cultivars, US-395 among the medium duration cultivars and Arize 6444 among the mid late duration cultivars in both the range of moisture regime which were significantly superior to all other cultivars.

4.1.1.3 Leaf area index (LAI)

The detail insight into the LAI values of 24 summer rice cultivars under two moisture regimes are presented in Table 4.4 clearly indicated that the values gradually increased up to 60 DAS in early duration cultivars and up to 75 DAS in all other group of cultivars. Moisture regime also influenced significantly the LAI of all cultivars at all the stages of growth.

The maximum LAI values of early group (≤ 100 days) of cultivars ranged between 3.33 to 4.67 under unstressed (0 kPa) condition and 3.00 to 4.44 under stressed condition (40 kPa). The corresponding values were in the range of 4.23 to 5.66 and 4.07 to 4.59 in mid early group, 4.98 to 5.79 and 3.76 to 5.62 in medium group cultivars and 4.77 to 5.70 and 4.24 to 5.63 in mid late group of cultivars. However, the differences in LAI values with two different moisture regimes were not so conspicuous in Shahabhazi and US 323 from early group, CR Dhan 202 from mid early group, US 395 from medium group and Arize 6444 from the mid late group where as in rest other varieties were more pronounced in all the groups and all the stages of crop growth.

Table 4.3 Tiller count m⁻² of the various summer rice cultivars under different moisture regime

VARIETY	15 DAS		30 DAS		45 DAS		60 DAS		75 DAS		At harvest	
	0 kPa	40 kPa	0 kPa	40 kPa	0 kPa	40 kPa	0 kPa	40 kPa	0 kPa	40 kPa	0 kPa	40 kPa
Shahabhagi	60	56	117	113	145	140	145	140	139	136	136	130
Mandakini	54	44	109	90	130	116	125	110	121	105	115	95
Khandagiri	56	47	115	97	140	122	137	119	134	110	128	93
ADV 1417	60	50	122	98	137	124	133	113	129	107	125	92
DRR Dhan 42	47	40	120	100	146	127	144	120	140	105	132	90
DRR Dhan 43	55	49	118	95	142	130	139	124	136	110	127	90
US 321	52	46	124	115	134	120	134	110	130	100	122	89
US 323	56	53	122	120	150	146	142	138	140	138	136	133
US 359	58	50	120	107	154	140	150	130	144	120	130	100
Naveen	71	64	152	140	224	210	315	300	311	290	299	276
Konark	77	68	158	147	230	219	310	292	308	284	295	265
CR Dhan 201	80	70	166	153	239	223	306	299	303	287	290	268
CR Dhan 202	85	82	160	157	245	242	322	318	317	313	311	307
CR Dhan 204	82	76	172	160	228	210	311	298	305	287	297	276
Arize 6129	90	80	210	203	265	245	300	275	362	330	355	319
Ajay	102	89	242	230	300	280	340	318	390	366	385	350
Rajlaxmi	107	92	256	240	324	310	364	349	403	389	398	374
Lalat	98	86	232	218	312	299	350	335	400	385	393	370
US 366	100	88	250	227	320	297	370	347	410	387	397	372
US 395	104	100	255	250	310	307	359	356	420	417	415	413
DRR Dhan 44	99	89	249	226	334	310	402	376	440	414	429	402
CR DHAN 701	115	104	265	242	345	322	413	392	451	440	444	427
Arize 6444	120	107	280	276	360	355	440	437	473	469	467	459
Arize Prima	110	95	265	240	350	310	428	408	466	426	456	407
MEAN	81	72	182	169	236	221	274	259	291	271	283	258
SEm(±) for C	0.2		0.6		1.8		2.1		3.08		4.4	
CD (P=0.05) for C	0.5		1.7		5.22		6.09		8.34		12.7	
M	S		S		S		S		NS		NS	

C-cultivar, M-moisture regime

Table 4.4 Leaf area index of various summer rice cultivars under two different moisture regimes

VARIETY	15 DAS		30 DAS		45 DAS		60 DAS		75 DAS		At harvest	
	0 kPa	40 kPa	0 kPa	40 kPa	0 kPa	40 kPa	0 kPa	40 kPa	0 kPa	40 kPa	0 kPa	40 kPa
Shahabhangi	0.83	0.77	1.22	1.17	2.13	2.09	3.33	3.25	3.23	3.17	2.02	1.97
Mandakini	0.92	0.43	1.34	1.12	2.25	2.02	3.45	3.09	3.33	3.00	1.76	1.44
Khandagiri	0.73	0.29	1.17	1.05	2.00	1.77	3.77	2.99	3.44	3.12	2.21	1.92
ADV 1417	1.37	1.03	2.22	1.76	3.09	2.82	4.25	3.75	4.06	3.87	3.42	2.73
DRR Dhan 42	1.04	0.66	1.92	1.66	2.98	2.21	3.55	3.00	3.32	3.07	2.33	1.98
DRR Dhan 43	0.98	0.59	1.86	1.47	3.02	2.88	4.49	3.97	4.33	4.10	3.24	2.23
US 321	1.26	0.98	2.04	1.55	3.22	2.78	4.45	4.22	4.35	3.96	3.43	2.54
US 323	1.44	1.38	2.28	2.19	3.34	3.26	4.67	4.44	4.50	4.04	3.88	3.85
US 359	1.32	1.21	2.12	1.98	3.19	2.95	4.40	4.13	4.27	3.89	2.79	2.33
Naveen	0.95	0.57	1.24	1.03	2.34	2.00	3.42	3.18	4.68	4.23	3.01	2.43
Konark	0.79	0.39	1.37	1.01	2.23	2.05	3.75	3.15	4.23	4.07	2.93	2.17
CR Dhan 201	0.89	0.43	1.19	1.02	2.23	2.08	3.37	3.03	4.53	4.39	2.75	2.19
CR Dhan 202	0.98	0.92	1.26	1.19	2.44	2.38	3.89	3.54	4.93	4.62	3.21	3.18
CR Dhan 204	0.90	0.47	1.20	1.00	2.38	2.05	3.76	3.19	4.89	4.29	3.07	2.88
Arize 6129	1.21	0.88	2.44	1.34	3.56	2.49	4.63	3.51	5.66	4.59	4.12	3.78
Ajay	1.35	0.93	2.56	1.53	3.70	2.65	4.76	3.62	5.63	4.57	4.33	2.96
Rajlaxmi	1.29	0.76	2.63	1.68	3.72	2.59	4.88	3.76	5.79	4.68	4.45	3.01
Lalat	0.96	0.62	1.34	1.00	2.89	1.98	3.86	2.75	4.98	3.76	3.72	3.23
US 366	1.25	0.98	2.44	1.48	3.67	2.54	4.81	3.76	5.82	4.75	4.32	3.39
US 395	1.37	1.28	2.59	2.56	3.79	3.76	4.92	4.90	5.66	5.62	4.51	4.46
DRR Dhan 44	1.13	0.85	2.34	1.17	3.85	2.78	4.90	3.86	5.55	4.43	4.26	3.98
CR DHAN 701	1.02	0.73	2.23	1.19	3.53	2.45	4.60	3.52	5.70	4.62	4.33	3.46
Arize 6444	1.50	1.45	2.76	2.72	3.89	3.85	4.89	4.86	5.69	5.63	4.58	4.49
Arize Prima	1.35	0.92	2.55	1.35	3.47	2.35	4.40	3.32	5.48	4.36	4.21	3.12
MEAN	1.12	0.81	1.93	1.47	3.04	2.53	4.22	3.62	4.75	4.20	3.45	2.91
SEm(±) for C	0.03		0.06		0.09		0.07		0.09		0.08	
CD (P=0.05) for C	0.09		0.2		0.27		0.23		0.27		0.26	
M	S		S		S		S		S		S	

C-cultivar, M-moisture regime

4.1.1.4 Canopy temperature

The ambient and canopy temperature of the rice cultivars as affected by the contrasting moisture regimes are presented in the Table 4.5 and 4.6.

The canopy temperature of all the cultivars were less than the ambient temperature in the 0 kPa moisture regime. However, the situations were just reversed beyond 15 DAS under moisture stressed condition i.e. at 40 kPa excepting few varieties like Shahabhazi and US-323 from early group, CRDhan 202 from mid early group, US 395 from medium group and Arize 6444 from mid-late group where the canopy temperature is less than the ambient temperature. The magnitude of the temperature difference between the canopy and the ambient temperature is a measure of the stress level of the plants. The differences were more pronounced up to 45 DAS as compared to the differences during later crop growth stages of all the summer rice cultivars irrigated at 40 kPa of moisture status in soil.

4.1.1.5 Normalized Difference Vegetative Index:

The NDVI values, the indicative of the greenness of the various rice cultivars as affected by the noble maintained moisture conditions and the moisture stress conditions are recorded in the Table 4.7.

The NDVI values of the cultivars in the 0 kPa moisture regime shows an increasing trend up to 40 DAS in the early duration cultivars, 60 DAS in mid early duration cultivars , 75 DAS in medium duration cultivars and mid late duration cultivars and then decreases at the time of harvest in all the cultivars.

However, the NDVI values of the cultivars Shahabhazi,US-323, CR Dhan 202, US-395 and Arize 6444 in the 40 kPa moisture regime were statistically at par with the corresponding NDVI values obtained in the 0 kPa moisture regime. The rest cultivars exhibited well marked difference in NDVI values in the stressed moisture regime in comparison to the non stressed moisture regime.

Table 4.5 Canopy temperature of the summer rice cultivars under 0 kPa moisture regime

VARIETY	15 DAS			30 DAS			45 DAS			60 DAS			75 DAS			At harvest		
	Tc	Ta	Diff.	Tc	Ta	Diff.	Tc	Ta	Diff.	Tc	Ta	Diff.	Tc	Ta	Diff.	Tc	Ta	Diff.
Shahabhazi	23	25.2	-2.2	25	27	-2	27.2	30	-2.4	29.3	31.2	-1.9	30.8	32.8	-2	31.3	35	-3.7
Mandakini	23.2	25.2	-2	25.2	27	-1.8	27.5	30	-2.1	29.3	31.2	-1.9	31	32.8	-1.8	32	35	-3
Khandagiri	23.3	25.2	-1.9	25	27	-2	27.4	30	-2.2	29.5	31.2	-1.7	31.4	32.8	-1.4	31.8	35	-3.2
ADV 1417	23.2	25.2	-2	25	27	-2	27.4	30	-2.2	29.4	31.2	-1.8	31.3	32.8	-1.5	32	35	-3
DRR Dhan 42	23.4	25.2	-1.8	25.3	27	-1.7	27.3	30	-2.3	29.5	31.2	-1.7	31.5	32.8	-1.3	32.3	35	-2.7
DRR Dhan 43	23.6	25.2	-1.6	25.4	27	-1.6	27.3	30	-2.3	29.3	31.2	-1.9	31	32.8	-1.8	32	35	-3
US 321	23.2	25.2	-2	25	27	-2	27.4	30	-2.2	29.5	31.2	-1.7	31.3	32.8	-1.5	31.5	35	-3.5
US 323	23.4	25.2	-1.8	25.2	27	-1.8	27.2	30	-2.4	29.4	31.2	-1.8	31	32.8	-1.8	32	35	-3
US 359	22.8	25.2	-2.4	25	27	-2	27.2	30	-2.4	29.3	31.2	-1.9	30.8	32.8	-2	32	35	-3
Naveen	23.3	25.2	-1.9	25.3	27	-1.7	27.4	30	-2.2	29.5	31.2	-1.7	31	32.8	-1.8	33.2	37.2	-4
Konark	23.2	25.2	-2	25	27	-2	27.3	30	-2.3	29.3	31.2	-1.9	31.4	32.8	-1.4	33	37.2	-4.2
CR Dhan 201	23.3	25.2	-1.9	25.4	27	-1.6	27.4	30	-2.2	29.5	31.2	-1.7	31.3	32.8	-1.5	33.5	37.2	-3.7
CR Dhan 202	22.8	25.2	-2.4	25	27	-2	27.2	30	-2.4	29.3	31.2	-1.9	31	32.8	-1.8	33	37.2	-4.2
CR Dhan 204	23.3	25.2	-1.9	25.2	27	-1.8	27.2	30	-2.4	29.5	31.2	-1.7	31.2	32.8	-1.6	33.8	37.2	-3.4
Arize 6129	24.2	25.2	-1	25	27	-2	27.4	30	-2.2	29.5	31.2	-1.7	31.3	32.8	-1.5	37.2	39	-1.8
Ajay	24	25.2	-1.2	25.4	27	-1.6	27.3	30	-2.3	29.3	31.2	-1.9	31	32.8	-1.8	37.5	39	-1.5
Rajlaxmi	24.4	25.2	-0.8	25	27	-2	27.4	30	-2.2	29.4	31.2	-1.8	31.3	32.8	-1.5	37.7	39	-1.3
Lalat	24.2	25.2	-1	25.2	27	-1.8	27.5	30	-2.1	29.6	31.2	-1.6	31	32.8	-1.8	37.4	39	-1.6
US 366	24	25.2	-1.2	25	27	-2	27.2	30	-2.4	29.5	31.2	-1.7	31.3	32.8	-1.5	37	39	-2
US 395	23.6	25.2	-1.6	25.2	27	-1.8	27.4	30	-2.2	29.3	31.2	-1.9	30.8	32.8	-2	37.4	39	-1.6
DRR Dhan 44	24	25.2	-1.2	25.4	27	-1.6	27.3	30	-2.3	29.5	31.2	-1.7	31.3	32.8	-1.5	37.3	39	-1.7
CR DHAN 701	24	25.2	-1.2	25	27	-2	27.2	30	-2.4	29.4	31.2	-1.8	31.4	32.8	-1.4	38	39.5	-1.5
Arize 6444	23.7	25.2	-1.5	25.3	27	-1.7	27.4	30	-2.2	29.3	31.2	-1.9	31	32.8	-1.8	38.2	39.5	-1.3
Arize Prima	24.2	25.2	-1	25	27	-2	27.2	30	-2.4	29.3	31.2	-1.9	31.3	32.8	-1.5	38	39.5	-1.5
MEAN	23.554	25.2	-1.6	25.146	27	-1.9	27.321	30	-2.3	29.404	31.2	-1.8	31.154	32.8	-1.6	34.54583	37.19	-2.64
SEm(±) for C	0.01			0.19			0.26			0.11			0.09			0.07		
CD (P=0.05) for C	0.029			0.57			0.8			0.33			0.27			0.2		
M	NS			S			S			S			S			S		

C-cultivar, M-moisture regime

Table 4.6 Canopy temperature of the summer rice cultivars under 40 kPa moisture regime.

VARIETY	15 days			30 days			45 days			60 days			75 days			At harvest		
	Tc	Ta	Diff.	Tc	Ta	Diff.	Tc	Ta	Diff.	Tc	Ta	Diff.	Tc	Ta	Diff.	Tc	Ta	Diff.
Shahabhazi	23	25	-2.2	25	27	-2	27.4	29.6	-2.2	30.8	31.2	-0.4	31.4	32.8	-1.4	33.2	35	-1.8
Mandakini	23.2	25	-2	27.4	27	0.4	30.6	29.6	1	31.9	31.2	0.7	33	32.8	0.2	35.7	35	0.7
Khandagiri	23.3	25	-1.9	27.5	27	0.5	31.2	29.6	1.6	31.7	31.2	0.5	33.1	32.8	0.3	35.4	35	0.4
ADV 1417	23.2	25	-2	27.6	27	0.6	30.8	29.6	1.2	31.5	31.2	0.3	33.1	32.8	0.3	35.8	35	0.8
DRR Dhan 42	23.4	25	-1.8	27.5	27	0.5	31	29.6	1.4	31.9	31.2	0.7	33.3	32.8	0.5	35.6	35	0.6
DRR Dhan 43	23.6	25	-1.6	27.4	27	0.4	30.6	29.6	1	31.5	31.2	0.3	33	32.8	0.2	35.2	35	0.2
US 321	23.2	25	-2	27.5	27	0.5	31.3	29.6	1.7	31.7	31.2	0.5	33.1	32.8	0.3	35.8	35	0.8
US 323	23.4	25	-1.8	27.4	27	0.4	30.8	29.6	1.2	31.5	31.2	0.3	33	32.8	0.2	33.6	35	-1.4
US 359	22.8	25	-2.4	25.3	27	-1.7	27.6	29.6	-2	30.6	31.2	-0.6	31.7	32.8	-1.1	35.2	35	0.2
Naveen	23.3	25	-1.9	27.5	27	0.5	30.8	29.6	1.2	32	31.2	0.8	33.1	32.8	0.3	37.8	37.2	0.6
Konark	23.2	25	-2	27.7	27	0.7	30.6	29.6	1	32.2	31.2	1	33.3	32.8	0.5	37.8	37.2	0.6
CR Dhan 201	23.3	25	-1.9	27.3	27	0.3	31.2	29.6	1.6	32	31.2	0.8	33.2	32.8	0.4	37.7	37.2	0.5
CR Dhan 202	22.8	25	-2.4	25.2	27	-1.8	28	29.6	-1.6	31	31.2	-0.2	31.8	32.8	-1	36.4	37.2	-0.8
CR Dhan 204	23.3	25	-1.9	27.3	27	0.3	30.8	29.6	1.2	32	31.2	0.8	33	32.8	0.2	37.5	37.2	0.3
Arize 6129	24.2	25	-1	27.4	27	0.4	31	29.6	1.4	32.2	31.2	1	33	32.8	0.2	39.4	39	0.4
Ajay	24	25	-1.2	27.7	27	0.7	30.6	29.6	1	32.2	31.2	1	33.2	32.8	0.4	39.7	39	0.7
Rajlaxmi	24.4	25	-0.8	27.5	27	0.5	31.2	29.6	1.6	32.3	31.2	1.1	33.1	32.8	0.3	39.5	39	0.5
Lalat	24.2	25	-1	27.6	27	0.6	30.8	29.6	1.2	32.4	31.2	1.2	33.2	32.8	0.4	39.3	39	0.3
US 366	24	25	-1.2	27.3	27	0.3	30.6	29.6	1	32.2	31.2	1	33	32.8	0.2	39.5	39	0.5
US 395	23.6	25	-1.6	25.4	27	-1.6	27.8	29.6	-1.8	30.9	31.2	-0.3	32	32.8	-0.8	38.2	39	-0.8
DRR Dhan 44	24	25	-1.2	27.2	27	0.2	31.2	29.6	1.6	32.6	31.2	1.4	33.1	32.8	0.3	39.6	39	0.6
CR DHAN 701	24	25	-1.2	27.4	27	0.4	30.6	29.6	1	32.5	31.2	1.3	33	32.8	0.2	39.8	39.5	0.3
Arize 6444	23.7	25	-1.5	25.3	27	-1.7	28	29.6	-1.6	31	31.2	-0.2	32.1	32.8	-0.7	38.6	39.5	-0.9
Arize Prima	24.2	25	-1	27.2	27	0.2	30.8	29.6	1.2	32.4	31.2	1.2	33	32.8	0.2	39.9	39.5	0.4
MEAN	23.554	25	-1.65	26.983	27	-0.017	30.221	29.6	0.621	31.792	31.2	0.59	32.825	32.8	0.03	37.34167	37.19	0.1542
SEm(±) for C	0.01			0.19			0.26			0.11			0.09			0.07		
CD (P=0.05) for C	0.029			0.57			0.8			0.33			0.27			0.2		
M	NS			S			S			S			S			S		

C-cultivar, M-moisture regime

Table 4.7 Normalized difference vegetative index of the summer rice cultivars under different moisture regimes

VARIETY	15 DAS		30 DAS		45 DAS		60 DAS		75 DAS		At harvest	
	0 kPa	40 kPa	0 kPa	40 kPa	0 kPa	40 kPa	0 kPa	40 kPa	0 kPa	40 kPa	0 kPa	40 kPa
Shahabhazi	0.29	0.25	0.39	0.32	0.48	0.43	0.59	0.53	0.55	0.51	0.44	0.34
Mandakini	0.16	0.17	0.25	0.22	0.39	0.36	0.47	0.45	0.42	0.39	0.27	0.14
Khandagiri	0.18	0.15	0.27	0.20	0.35	0.31	0.43	0.40	0.41	0.40	0.24	0.18
ADV 1417	0.25	0.20	0.36	0.31	0.47	0.40	0.59	0.49	0.52	0.45	0.42	0.31
DRR Dhan 42	0.28	0.26	0.39	0.30	0.48	0.41	0.55	0.52	0.53	0.52	0.32	0.19
DRR Dhan 43	0.25	0.20	0.36	0.29	0.44	0.35	0.52	0.44	0.50	0.42	0.30	0.15
US 321	0.30	0.25	0.45	0.37	0.58	0.49	0.65	0.56	0.61	0.52	0.34	0.22
US 323	0.19	0.19	0.28	0.25	0.38	0.32	0.45	0.40	0.43	0.38	0.38	0.30
US 359	0.27	0.23	0.35	0.34	0.44	0.42	0.56	0.50	0.53	0.52	0.49	0.44
Naveen	0.35	0.30	0.48	0.41	0.59	0.50	0.67	0.63	0.78	0.72	0.44	0.31
Konark	0.32	0.17	0.44	0.21	0.56	0.30	0.66	0.39	0.72	0.41	0.54	0.22
CR Dhan 201	0.37	0.29	0.44	0.38	0.58	0.49	0.69	0.65	0.75	0.70	0.40	0.22
CR Dhan 202	0.39	0.35	0.50	0.50	0.65	0.62	0.72	0.70	0.80	0.77	0.52	0.47
CR Dhan 204	0.32	0.28	0.48	0.39	0.60	0.50	0.69	0.58	0.73	0.62	0.43	0.31
Arize 6129	0.45	0.40	0.57	0.49	0.68	0.60	0.75	0.72	0.82	0.79	0.66	0.39
Ajay	0.49	0.42	0.59	0.50	0.70	0.66	0.78	0.75	0.85	0.80	0.69	0.27
Rajlaxmi	0.50	0.46	0.62	0.56	0.73	0.67	0.82	0.76	0.88	0.84	0.65	0.22
Lalat	0.40	0.36	0.56	0.35	0.67	0.48	0.75	0.59	0.79	0.70	0.48	0.18
US 366	0.41	0.38	0.55	0.49	0.69	0.60	0.78	0.69	0.80	0.75	0.44	0.27
US 395	0.49	0.47	0.58	0.56	0.69	0.66	0.80	0.78	0.88	0.86	0.67	0.62
DRR Dhan 44	0.42	0.39	0.51	0.48	0.62	0.57	0.75	0.69	0.80	0.76	0.59	0.38
CR DHAN 701	0.49	0.44	0.59	0.56	0.68	0.62	0.79	0.73	0.88	0.80	0.63	0.41
Arize 6444	0.52	0.50	0.63	0.60	0.74	0.72	0.87	0.84	0.95	0.92	0.68	0.60
Arize Prima	0.50	0.45	0.61	0.58	0.70	0.63	0.81	0.72	0.90	0.85	0.52	0.31
MEAN	0.36	0.32	0.47	0.40	0.58	0.50	0.67	0.60	0.70	0.64	0.48	0.31
SEm(±) for C	0.0043		0.0087		0.0078		0.0073		0.006		0.023	
CD (P=0.05) for C	0.013		0.0261		0.0235		0.022		0.018		0.069	
M	S		S		S		S		S		S	

C-cultivar, M-moisture regime

4.1.2 Post harvest studies

4.1.2.1 Length of panicle (cm)

Data on length of panicle is presented in the Table 4.8.

Significant difference in length of panicle was noted due to varieties along with well marked difference in panicle length of the same varieties in different moisture regimes. The maximum panicle length of 30.0 cm and 28.70 cm was recorded in cultivar Arize 6444 under 0 kPa and 40 kPa moisture regime, respectively. Whereas, the lowest panicle length of 20.05 cm was measured in the cultivar ADV-1417 under moisture stress condition (40 kPa).

4.1.2.2 Number of filled grain per panicle

Data on number of filled grains panicle⁻¹ as influenced by different summer rice cultivars and various moisture regimes are presented in Table 4.8.

Number of filled grains in different moisture regimes varied significantly. It was highest in Ajay (122) and lowest in US 359 (97) in the 0 kPa moisture regime. However, the lowest filled grains panicle⁻¹ was recorded in the cultivar Arize 6129 and US-359 (86) and the highest filled grains panicle⁻¹ was recorded in the cultivar Shahabhagi (114) under 40 kPa moisture regimes. The values recorded for the rest cultivars exhibited a significant difference when the comparison took place amidst the different moisture regimes.

4.1.2.3 Spikelet fertility percentage

Data on spikelet fertility percentage of grain are presented in the Table 4.8

Insight into result of spikelet fertility percentage with respect to 0 kPa moisture regime was recorded highest in cultivar Ajay (93.5%) which was statistically at par with Rajlaxmi having a spikelet fertility percentage of 92.8 and highest in cultivar Shahabhagi in the 40 kPa moisture regime with a value of 91%.

4.1.2.4 Test weight (gm)

Data on test weight (1000 grain weight) as influenced by different rice varieties and moisture regimes are presented in the Table 4.8.

Table 4.8 Yield attributes of various summer rice cultivars as influenced by differential moisture regime

VARIETY	Panicle length (cm)		Filled grains/panicle		Spikelet fertility (%)		Test weight (g)	
	0 kPa	40 kPa	0 kPa	40 kPa	0 kPa	40 kPa	0 kPa	40 kPa
Shahabhazi	22.60	22.00	120	114	91.65	91.00	23.60	23.42
Mandakini	25.00	21.28	105	90	88.50	77.00	21.00	18.84
Khandagiri	23.50	20.17	102	89	88.00	78.00	21.50	19.67
ADV 1417	24.85	20.05	101	96	88.20	77.00	25.00	22.55
DRR Dhan 42	23.94	22.00	104	98	89.00	77.50	24.50	22.02
DRR Dhan 43	24.18	21.89	100	89	90.00	78.00	23.80	21.28
US 321	23.82	20.67	110	92	89.50	76.00	22.60	20.78
US 323	25.38	24.89	115	110	90.00	86.80	22.60	25.94
US 359	24.07	21.75	97	86	87.60	75.00	23.80	21.04
Naveen	27.64	24.8	103	93	88.00	77.20	22.70	20.56
Konark	25.37	22.12	110	105	90.00	79.40	23.80	21.67
CR Dhan 201	26.49	22.34	105	93	88.80	76.20	25.00	22.15
CR Dhan 202	28.26	27.98	104	100	88.00	85.50	24.20	23.47
CR Dhan 204	27.08	24.23	111	99	90.40	78.00	22.80	20.28
Arize 6129	27.68	21.52	99	86	91.50	77.00	23.50	20.36
Ajay	26.53	20.45	122	107	93.50	75.70	24.70	20.56
Rajlaxmi	28.49	21.85	118	101	92.80	77.00	26.00	22.22
Lalat	22.00	18.22	108	99	91.00	77.00	22.80	19.87
US 366	24.95	20.85	115	100	92.00	77.50	23.40	20.29
US 395	25.76	24.22	106	103	92.20	90.00	25.50	24.86
DRR Dhan 44	26.88	21.57	100	91	91.50	77.00	24.80	21.50
CR DHAN 701	29.38	22.59	101	90	91.80	79.00	25.30	22.45
Arize 6444	30.00	28.70	100	99	92.00	90.80	26.50	26.14
Arize Prima	29.25	24.86	102	98	92.50	82.30	24.50	22.48
MEAN	25.96	22.54	107	97	90.35	79.83	23.91	21.85
SEm(±) for C	0.39		0.91		0.73		0.57	
CD (P=0.05) for C	1.18		2.73		2.17		1.71	
M	S		S		S		S	

C-cultivar, M-moisture regime

The highest test weight was recorded in the cultivar Arize 6444 in both the moisture regimes (26.5 gm in 0 kPa and 26.14 gm in 40 kPa) being statistically at par with US 323 (26.0g), US 395(25.5g), CR Dhan701 (25.3g), ADV1417 (25.0 g) and CR Dhan 201 (25.0g) and significantly superior to rest other varieties. The lightest grains were noticed with test weight of 21.0 and 18.84 g in cultivar Mandakini under 0 and 40 kPa moisture regimes, respectively.

4.1.2.5 Grain yield (t ha⁻¹)

Data on grain yield as influenced by the various moisture regimes are presented in the Table 4.9.

Perusal of data revealed that the grain yield of various cultivars showcased significant difference among each other under both the moisture regimes. However, the differences in grain yield of cultivars Shahabhazi, US-323, CR Dhan 202, US-395 and Arize 6444 were not so conspicuous even under moisture stressed condition as compared to the non stressed situation. Further insight into the data indicated that hybrids like US-321, US-323, Arize 6129, Ajay, Rajlaxmi recorded higher grain yield in noble conditions of moisture, but they failed to record the phenomenal yield when the irrigations were supplemented to these cultivars at 40 kPa moisture regime. Cultivars DRR Dhan 42, Naveen, Konark, DRR Dhan 44, Ajay, Lalat, Rajlaxmi recorded yield reduction by 18%, 19%, 20%, 22%, 23% ,26% and 29%, respectively, when grown under moisture stressed condition.

4.1.2.6 Straw Yield (t ha⁻¹)

Data related to straw yield of various summer rice cultivars as found under different moisture regime are presented in the Table 4.9.

The highest straw yield was obtained from DRR Dhan 42 in the early duration, US-359 in the mid early duration, Arize 6129 in the medium duration and CR Dhan701 in the mid late duration cultivars group in the 0 kPa moisture regime. Whereas under stressed condition DRR Dhan 43 from early group, Arize 6129 in the mid early section, US-395 in the medium group and Arize 6444 in the mid late group recorded highest straw yield in their respective duration groups.

Table 4.9 Grain yield, straw yield and harvest index of the summer rice cultivars under different moisture regimes

VARIETY	Grain yield (t /ha)		Straw yield (t/ha)		Harvest index (%)	
	0 kPa	40 kPa	0 kPa	40 kPa	0 kPa	40 kPa
Shahabhazi	4.2	4.0	4.6	4.4	47.9	47.0
Mandakini	3.4	2.9	4.7	4.5	42.0	39.0
Khandagiri	3.2	2.5	4.8	4.4	40.0	36.3
ADV 1417	4.0	3.6	5.0	5.4	44.3	40.0
DRR Dhan 42	3.9	3.2	6.0	5.2	39.0	37.5
DRR Dhan 43	4.2	4.0	6.0	6.5	41.2	38.0
US 321	4.3	3.8	5.5	5.4	44.0	41.3
US 323	4.5	4.2	5.5	5.2	45.0	44.3
US 359	4.2	3.8	5.6	5.8	43.0	39.5
Naveen	3.7	3.0	5.5	5.3	40.1	36.0
Konark	3.6	2.9	4.9	4.5	42.5	39.0
CR Dhan 201	3.9	3.3	5.4	5.3	41.7	38.2
CR Dhan 202	4.0	3.8	4.5	4.4	46.8	46.3
CR Dhan 204	3.7	3.1	4.8	4.6	43.6	40.2
Arize 6129	6.5	5.9	8.9	9.3	42.0	38.7
Ajay	7.3	5.6	8.6	8.4	46.0	40.0
Rajlaxmi	7.4	5.2	8.4	7.4	46.8	41.2
Lalat	4.4	3.2	5.8	5.1	43.0	39.0
US 366	6.4	5.9	8.2	8.3	43.8	41.5
US 395	7.0	7.0	8.5	8.5	45.3	45.0
DRR Dhan 44	5.5	4.3	7.6	7.0	42.0	38.0
CR DHAN 701	6.5	5.7	7.9	7.5	45.2	43.4
Arize 6444	6.9	6.7	7.7	7.7	47.0	46.5
Arize Prima	6.7	5.8	7.7	8.6	46.3	40.3
MEAN	5.0	4.3	6.3	6.2	43.7	40.7
SEm(±) for C	0.1		0.1		0.4	
CD (P=0.05) for C	0.31		0.26		1.05	
M	S		S		S	

C-cultivar, M-moisture regime

4.1.2.7 Harvest index (HI)

Data pertaining to HI are presented in Table 4.9.

Highest HI values were observed in Shahabhazi amidst the early, CR Dhan 202 among the mid early, US-395 from the medium and Arize 6444 among the mid late duration groups under both the moisture regimes. Whereas, the lowest HI values in 0 kPa moisture regime was obtained from DRR Dhan 42 (39.0%) and in the 40 kPa moisture regime was obtained from Khandagiri (36.3%).

4.1.3 Irrigation water requirement and water use efficiency

Data relating to irrigation water requirement and water use efficiency are presented in Table 4.10.

The water use efficiency of all the cultivars was higher in 40 kPa as compared to that in 0 kPa. In the non stressed moisture regime, the early duration, mid early duration, medium duration and mid late duration cultivars required 12, 14, 16 and 18 number of irrigations respectively during the entire period of crop growth. As the depth of water applied in each irrigation was 5 cm, the water requirement of the early duration, mid early duration, medium duration and mid late duration cultivars can be expressed as 60, 70, 80 and 90 ha-cm of irrigation water respectively.

The irrigation water requirement varied considerably in the early duration, mid early duration, medium duration and mid late duration cultivars as they required 8,10, 12 and 14 number of irrigations in the 40 kPa moisture regime during the entire period of crop growth.

The water use efficiency (WUE) of the cultivars Shahabhazi, US -323, CR Dhan 202, US-395 and Arize 6444 were 42.85%, 40.00 %, 33.09%, 33.30% and 24.77% higher in the stressed moisture regime than the 0kPa moisture regime.

Table 4.10 Irrigation water requirement (cm) and water use efficiency (kg/ha-cm) of the summer rice cultivars under different moisture regimes

VARIETY	0 kPa			40 kPa		
	YIELD	WR	WUE	YIELD	WR	WUE
Shahabhagi	4200.0	60	70.0	4000.0	40	100.0
Mandakini	3400.0	60	56.7	2900.0	40	72.5
Khandagiri	3200.0	60	53.3	2500.0	40	62.5
ADV 1417	4000.0	60	66.7	3600.0	40	90.0
DRR Dhan 42	3900.0	60	65.0	3200.0	40	80.0
DRR Dhan 43	4200.0	60	70.0	4000.0	40	100.0
US 321	4300.0	60	71.7	3800.0	40	95.0
US 323	4500.0	60	75.0	4200.0	40	105.0
US 359	4200.0	60	70.0	3800.0	40	95.0
Naveen	3700.0	70	52.9	3000.0	50	60.0
Konark	3600.0	70	51.4	2900.0	50	58.0
CR Dhan 201	3900.0	70	55.7	3300.0	50	66.0
CR Dhan 202	4000.0	70	57.1	3800.0	50	76.0
CR Dhan 204	3700.0	70	52.9	3100.0	50	62.0
Arize 6129	6500.0	70	92.9	5900.0	60	98.3
Ajay	7300.0	80	91.3	5600.0	60	93.3
Rajlaxmi	7400.0	80	92.5	5200.0	60	86.7
Lalat	4400.0	80	55.0	3200.0	60	53.3
US 366	6400.0	80	80.0	5900.0	60	98.3
US 395	7000.0	80	87.5	7000.0	60	116.7
DRR Dhan 44	5500.0	80	68.8	4300.0	60	71.7
CR DHAN 701	6500.0	90	72.2	5700.0	70	81.4
Arize 6444	6900.0	90	76.7	6700.0	70	95.7
Arize Prima	6700.0	90	74.4	5800.0	70	82.9

4.1.4 Economics

Data pertaining to cost of cultivation, gross return, net return and B:C ratio has been presented in the Table 4.11.

Cost of cultivation varied mainly according to the type of the cultivars, duration of the cultivars and number of irrigations applied. The gross return was influenced by the yield of the various duration cultivars in the different soil moisture regimes.

The highest B:C ratio of 1.64, 1.80, 1.66, 1.81 and 1.72 was obtained against net return of ₹ 15,825/-, 20,160/-, 17,326/-, 23, 652/- and 23,328/- respectively in stressed moisture regime for Shahabhagi, US-323, CR Dhan 202, US-395 and Arize 6444, respectively, in the early, mid early, medium and mid late duration cultivars, respectively.

Table 4.11 Economics of summer rice cultivars as influenced by different soil moisture regimes

Variety	0 kPa				40 kPa			
	Cost of Cultivation(₹)	Gross Return (₹)	Net Return (₹)	B:C	Cost of Cultivation(₹)	Gross Return(₹)	Net Return(₹)	B:C
Shahabhazi	25526	42430	16904	1.66	24726	40551	15825	1.64
Mandakini	25526	36502	10976	1.43	24726	32638	7912	1.32
Khandagiri	25526	35225	9699	1.38	24726	31897	7171	1.29
ADV 1417	26000	39520	13520	1.52	25200	35280	10080	1.40
DRR Dhan 42	25526	37778	12252	1.48	24726	33627	8901	1.36
DRR Dhan 43	25526	43139	17613	1.69	24726	35605	10879	1.44
US 321	26000	44460	18460	1.71	25200	34776	9576	1.38
US 323	26000	47580	21580	1.83	25200	45360	20160	1.80
US 359	26000	43680	17680	1.68	25200	38556	13356	1.53
Naveen	27052	38414	11362	1.42	26252	36228	9976	1.38
Konark	27052	36250	9198	1.34	26252	32815	6563	1.25
CR Dhan 201	27052	35709	8657	1.32	26252	32552	6300	1.24
CR Dhan 202	27052	45718	18666	1.69	26252	43578	17326	1.66
CR Dhan 204	27052	40578	13526	1.50	26252	37278	11026	1.42
Arize 6129	30000	54000	24000	1.80	29200	43508	14308	1.49
Ajay	29200	53144	23944	1.82	28400	40896	12496	1.44
Rajlaxmi	29200	51392	22192	1.76	28400	39192	10792	1.38
Lalat	29200	42340	13140	1.45	28400	36636	8236	1.29
US 366	30000	47100	17100	1.57	29200	42340	13140	1.45
US 395	30000	54300	24300	1.81	29200	52852	23652	1.81
DRR Dhan 44	29200	51976	22776	1.78	28400	44304	15904	1.56
CR DHAN 701	32780	53759	20979	1.64	31980	48610	16630	1.52
Arize 6444	33200	58100	24900	1.75	32400	55728	23328	1.72
Arize Prima	33200	51460	18260	1.55	32400	46008	13608	1.42



DISCUSSION

Rice productivity is an inter-play of several biotic and abiotic factors. Thus, development of plant through varying phenophases needs to be successful to achieve desired level of yield, may be close to its potential. Declining water resources has threatened the food security and also posed several new challenges to rice scientists to keep pace with food requirement of burgeoning population. This led to the development of the moisture stress tolerant cultivars. These cultivars promise statistically at par yield in even in the moisture deficit conditions with that of the cultivars grown in novel maintained moisture conditions. Thus, it was thought worthwhile to plan an experiment on “Performance of non puddled transplanted summer rice (*Oryza sativa* L.) cultivars under different moisture regimes ” to explore the possibilities of harnessing the yield of 24 promising rice cultivars of different maturity group grown under different hydrological situations, their performance evaluation and to find the reasons thereof so as to establish the cause and effect relationship under sub-humid condition of Bhubaneswar.

5.1 Weather and crop

In spite of its ability to adopt itself under various geo-hydrological situations across the seasons, rice too needs a favourable set of environment for its normal growth and development and to produce its best in terms of yield. The experimental site is located at 20° 15' N latitude and 82° 52' E longitude and, therefore provides typical sub-tropical climate for the growth of rice plant. The crop during its growing period from January 2015 to June 2015 received 242.73mm rainfall. It was 100.97 mm (29.3%) less than the three decadal mean (1985-2014) rainfall of 343.7mm .

Temperature and number of bright sunshine hours bore a direct effect on physiological processes by way of influencing rate of transpiration, exchange of gases and the rate of photo- respiration, thereby influencing the rice yield. The atmospheric temperature during the crop growing period was 28.2°C with a mean seasonal range of 21.72- 34.6°C. Yosida (1978) reported a temperature range of 25- 30, 25-28, 25-31 and 20-29°C as the optimum temperature for rice establishment, rooting, tillering and ripening, respectively. Thus, the crop almost underwent a favourable atmospheric regime.

Average bright sunshine hours per day ranged between 7.67 in 3rd meteorological week to 8.4 in 23rd meteorological week. Moomaw and Vergara (1964) concluded that for the realisation of yield of rice close to that of potential, the accumulated BSH should be around 240 during the last 30 days of crop growth. In the present investigation, the total BSH during the same period of crop growth was 164.61. It was 31.4 % less than the optimum requirement of 240. This might be one of the reasons of relatively lesser yield obtained in the novel maintained moisture conditions irrespective of the genotypes. Mean relative humidity during the period was 67.15% with the highest of 94.71% in 12th meteorological week and the lowest of 41% in the 4th and 5th meteorological week. The range can be considered as close to optimum range of 70-80% as reported by Angladette (1966).

5.2 Phenology of the summer rice cultivars

Various duration of summer rice cultivars were studied in the experiment with special reference to their phenology. The duration of the summer rice cultivars ranged from early duration to mid late duration due to which there was phenomenal changes observed in their phonological behaviour.

In the 40 kPa moisture regime, the early duration cultivars required an average GDD (Growing Degree Days) of 1495.62 to attain the stage of physiological maturity. The lowest GDD of 1391.5 was required by the cultivar Khandagiri to attain the physiological maturity and the highest of 2584.2 GDD was required by the cultivar Arize 6444 to attain the stage of physiological maturity. The mid early duration cultivars, medium duration cultivars and mid-late duration cultivars required an average GDD of 1726.53, 2015.22 and 2368.68, respectively, to attain physiological maturity.

In the 0 kPa moisture regime, the early duration, mid early duration, medium duration and mid late duration cultivars required an average GDD of 1664.02, 1942.38, 2370.6 and 2621.91, respectively, to attain physiological maturity.

The lowering of average GDD values by 168.4 in early duration cultivars, 215.85 in mid early duration cultivars, 355.38 in medium duration cultivars and 253.23 in mid late duration cultivars in the moisture stress regime clearly indicated shortening of duration which occurred due to forced maturity of the cultivars resulting

in attainment of physiological maturity faster or earlier in the moisture stress regime than the noble maintained moisture conditions. The cultivars like Shahabhazi, US-323, CR Dhan 202, US-395, Arize 6444 did not exhibit any appreciable reduction in their GDD requirement for attaining physiological maturity which highlights the fact that there was also no appreciable reduction in their duration and no signs of forced maturity were reported from these cultivars.

5.3 Growth and development

Successful completion of various crop stages is of paramount importance for realising higher productivity. Growth is represented by an increase in weight over a passage of time while passing through the successive morphologically different phases is the development. Both these phenomena are controlled by genetic makeup of the variety and the environment in which it is grown that controls various biochemical and physiological processes.

Growth was highly influenced in the various cultivars under differential moisture regimes. Hazra *et al.* (2016) studied tiller optimization is one of the core principles to increase productivity . Rice plants, only achieve their full tillering and production potential when transplanted before entering their fourth phyllochron of growth and when grown under favourable soil moisture conditions. Significant variation appeared in tiller productivity and mortality with variable water regime maintained through irrigation schedule. Mild to prolonged stress significantly increased tiller production but, large number of tillers not converted to effective tillers (ear bearing tillers) due to higher tiller mortality under water stress conditions. Tiller survival (non-mortality) might be viewed as an “efficiency” criterion with respect to plant development, in response to agronomic management practices. This particular trend might be due to reduced hypoxic condition which favored more root growth and less root degeneration which ultimately results in more tillers m⁻². The yield advantages of stress tolerant rice cultivars over other rice cultivars were mainly associated with more number of effective tillers per unit area. In this context, the differential tillering potential of rice varieties may obviously have variable response.

There lies a casual relationship among the various plant characters, the biochemical and physiological processes that determine the source size, source intensity and the size of sink. Leaves are considered as the major plant organ that cuts off the

insolation of sun for use and convert it to chemical energy and manufacture the food. The source size, thus determines the dry matter accumulation through the process of photosynthesis. Therefore, the crop growth depends upon the source size and its intensity with which it intercepts the photosynthetically active radiation. However, Watson (1952) concluded that leaf area is more important and proven determinant of plant growth than the photosynthetic capacity of individual leaf. Therefore, it also becomes appropriate to express leaf area of a crop per unit land area basis which is referred as the leaf area index. In the present study the leaf area index of the various cultivars was measured from 15 days after sowing to until the harvest of the crop keeping in view the conclusion drawn by Sarwar *et al.* (2013), who reported that leaf area index at around the heading stage is critical for the crop performance which decreases thereafter due to decrease in number of functional leaves. Result from the present study indicated that leaf area index varies with a considerable difference due to differential moisture regimes. The leaf area index of the cultivars raised in the noble maintained moisture conditions is significantly higher than the 40 kPa moisture regime. This is because leaf area is a fundamental determinant of the total photosynthesis of a plant. Leaf area always shows a positive relationship with net photosynthetic activity, because leaf enlargement is attributed to increase in number and width of grana and also high degree of stacking of grana (Flore et al., 1985). Leaf area development is based on the length and width of leaf, in general, was very sensitive to water deficit in rice . Water stress decreases the leaf area due to reduced cell division and cell enlargement which could be caused by accumulation of unexpanded cells during the cycle. These results were in tune to the findings of Sarwar *et al* (2013). observing that leaf area increases with an increase in water supply because plants are able to photosynthesize more efficiently. This is because that an increased accumulation of photosynthates accelerates the pace of growth which in turn is reflected by vigorous plant growth. There was an increase in leaf width with an increase in soil water regimes. This is because water is important for biochemical and physiological processes that lead to organ growth and development. The NDVI values of the summer rice cultivars obtained at various phenological stages for the different cultivars was in accordance of the study conducted by Wang Lin (2014). The maximum of NDVI always occurred at the beginning of heading and flowering stage. When rice grains become filling and ripening, leaves continue to senesce and gradually turn into yellowish or golden due to a decrease of chlorophyll

pigments. This ripening period is also characterized by a decrease in the number of leaves and a drop in leaf and stem moisture. So NDVI showed a decreasing trend. The differences of NDVI dynamics among the various duration cultivars might be caused by the fact that growth and duration of certain summer rice cultivars was significantly longer than that of other rice cultivars. Mid late rice cultivars still had green leaves and strong stem at the late growth stages, while the early cultivars tends to senescence early.

Transpiration in plant canopies occurs as a consequence of stomatal opening for the uptake of CO₂ for photosynthesis and to keep the canopy cool and avoid heat damage. Under moisture deficits, plant canopies can increase in temperature as the plant undergoes partial stomatal closure to maintain hydration. Persistently high canopy temperatures can lead to significant stress and the subsequent decrease in growth and yield. Higher canopy temperature were recorded in the moisture stress susceptible cultivars like Ajay, Rajlaxmi, Lalat, DRR Dhan 44, CR Dhan 201, CR Dhan 204, Naveen, Konark, Khandagiri, Mandakini and lower canopy temperature were recorded in moisture stress tolerant cultivars like Shahabhagi, US-323, CR Dhan 202, US-395 and Arize 6444. The findings were in accordance to Wen-zhong *et al.* (2007). The crop canopy temperature relies on energy exchange between the crop surface and the atmosphere, which is determined by sensible heat flux and the latent heat flux in SPAC (Soil-Plant-Atmosphere Continuum). Especially the latent heat exchange is a primary cause leading to spatial variation of canopy temperature. Therefore, the crop canopy temperature closely correlated to the moisture stress could be used to monitor crop water status, and among the environmental factors (light intensity, air temperature, wind speed and saturated vapor difference) canopy temperature is mainly depended on the daily air temperature, so canopy-air temperature difference has been taken as the index to determine crop water status in many crops would be regarded as one of the determinants for reasonable irrigation and drought analysis. Water status of rice could be reflected by the canopy-air temperature difference from 13:00 to 15:00 hours, and it was also affected by weather conditions. However, not all canopy-air temperature differences at the given time of day could be used to reflect the crop water conditions. 13:00 hours was the suitable measuring time at which the temperature difference could reflect the rice water conditions better. The smallest absolute value of the accumulative canopy-air temperature difference from 13:00 to 15:00 hours was observed. Moreover, the

canopy-air temperature differences were significant among water stress treatments. The lower soil water content resulted in smaller absolute value of the temperature difference and lower yield, with less filled grain number per panicle. In addition, the lower the soil water content was, the earlier the peak flowering time was. In the lowest water content treatments, the peak flowering time occurred in the first three days, causing short panicle length and light panicle weight.

5.4 Yield and yield attributes

Yield of any genotypes is the interplay of its genetic characteristics and the environment in which the genotype is grown. The improvement in grain yield can be achieved by certain characters having a direct influence on yield of the crop. Yosida (1972) opined that yield of rice can be improved by increasing grain size as the growth is restricted by the size of hull. The relationship among the yield attributing characters, can be expressed as

$$\text{Grain yield} = f(\text{EBT m}^{-2}, \text{Sp}^{-1}, \% \text{FGP}^{-1}, \text{T}_{\text{wt}})$$

$$\text{Where EBT} = \text{number of ear bearing tiller m}^{-2}$$

$$\text{SP} = \text{Number of spikelets panicle}^{-1}$$

$$\% \text{FGP} = \text{Percent filled grain panicle}^{-1}$$

$$\text{T}_{\text{wt}} = \text{Test weight of grain (g)}$$

Summer rice cultivars like Shahabhagi, US-323, CR Dhan 202, US-395 and Arize 6444 recorded grain yield in 40kPa moisture regime which was statistically at par with the grain yield noted from these cultivars at 0 kPa moisture regime. However, cultivars like Ajay, Rajlaxmi, DRR Dhan 42, DRR Dhan 43, ADV 1417, CR Dhan 701, US-366 which recorded a high grain yield in the noble maintained moisture conditions failed to produce that specified grain yield in 40 kPa moisture regime. This outcome was the result of the interplay between the various moisture regime and the different summer rice cultivars studied in the experiment. Increased unfilled grains per panicle under deficit soil moisture level was in accordance to the study of Abbasi *et al.* (2011) due to inactive pollen grain for dryness, incomplete development of pollen tube; insufficient assimilates production and its distribution to grains. The decrease in grain yield and other yield attributing parameters are in accordance to the study of Sokoto *et al.* (2014). Lower soil moisture decreased

translocation of assimilates to the grain which lowered grain size. But the degree of reduction in 1000 grain size weight was different in different genotypes. Yield reduction due to water stress could be as a result of reduction in photosynthesis and translocation of assimilates. Moreover, water stress might lead to a considerable increase in secondary rachis branch abortion and resulted in a reduction in spikelets number per panicle. In addition, drought stress could curtail the kernel sink potential by reducing the number of endosperm cells and amyloplasts formed. Therefore, the rate of reduction in grain weight is correlated to the reduction in the capacity of the endosperm to accumulate starch in terms of both rate and duration. Deshmukh *et al.* (2007) reported that grain filling is closely linked to the whole plant senescence process. Usually, water stress at grain filling induces early senescence and shortens the grain filling period but increases remobilization of assimilates from the straw to the grains. Naturally in rice, earlier flowering superior spikelets, usually located on apical primary branches, fill fast and produce larger and heavier grains. The results obtained from the experiment were in accordance to the study of Deshmukh *et al.* (2007) as higher test weight in comparison to other cultivars was recorded in the early duration cultivar US-323. While late flowering inferior spikelets usually located on proximal secondary branches, are either sterile or fill slowly and poorly to produce grains unsuitable for human consumption. The slow grain filling rate and low grain weight of inferior spikelets have often been attributed to a limitation in carbohydrate supply. There was a linear relationship between available water and yield, where reduction in available water limits evapotranspiration and consequently reduced yield. Harvest index, also referred as coefficient of efficiency, is a measure of quantity of translocation trend of photosynthates from source to sink and indicated by the higher values. Decrease in harvest index is largely due to water stress which resulted to decrease in translocation of assimilates to the grains, which lowered grain weight and increased the chaffy grains.

5.5 Water requirement and water use efficiency

The looming water crises have threatened the rice production scenario throughout the world. Different rice growing environment do suffer because of uneven distribution of rainfall thus undergoes differential soil moisture deficit stress in its growing period. On the other hand insufficient availability of water in irrigated ecosystems also affects the rice productivity adversely. Availability of moisture stress

tolerant varieties in rice provides an opportunity to raise the crop in areas where in supplemental irrigation is provided when rainfall is practically insufficient. Water use efficiency is a ratio of economic yield to the amount of water applied under field condition. The data indicated an average field water use efficiency of 88.8, 64.40, 88.33 and 86.66 kg ha⁻¹cm for early, mid early, medium and mid late duration cultivars respectively, under moisture stress condition. Higher water use efficiency of the cultivars was reported in moisture stress condition which is in tune to the study conducted by Mishra *et al.* (2012).

5.6 Economics

Cultivars Shahabhagi, US-323, CR Dhan 202, US-395 and Arize 6444 were found to be economically superior than the rest of the cultivars in early, mid early, medium and mid late duration, respectively as they recorded the highest B:C ratio of 1.64, 1.80, 1.66, 1.81, 1.72, respectively in their respective duration groups. So, these summer rice cultivars can be recommended to the farmers as they are moisture stress tolerant, produce higher yields in their respective durations, have higher WUE and fetch good economic returns to the farmer than the rest other cultivars of the same duration group.



SUMMARY AND CONCLUSION

A field experiment entitled “Performance of non puddle transplanted summer rice (*Oryza sativa* L.) cultivars under different moisture regimes” was conducted in alpha lattice design with 24 summer rice cultivars (Shahabhazi, Mandakini, Khandagiri, ADV 1417, DRR Dhan 42, DRR Dhan 43, US-321, US-323, US-359, Naveen, Konark, CR Dhan 201, CR Dhan 202, CR Dhan 204, Arize 6129, Ajay, Rajlaxmi, Lalat, US-366, US-395, DRR Dhan 44, CR dhan 701, Arize 6444, Arize Prima) as first factor and moisture regime (0 kPa- non stressed and 40 kPa- stressed) as the second factor during summer season of 2015-16 at Agronomy Main Research Farm, Department of Agronomy, OUAT, Bhubaneswar. The soil of the experimental site was sandy loam in texture with pH 5.8 having organic carbon 0.41% and EC 0.040 dS m⁻¹. The available nitrogen, phosphorus and potassium were 245.2, 43.4 and 166.8 kg ha⁻¹, respectively. The crop was fertilized with a uniform dose of 80-40-40 kg N, P₂O₅ and K₂O ha⁻¹. All the phosphorus, potassium was applied as basal and nitrogen was applied in 1:2:1 split as basal, at tillering and at panicle initiation stage respectively.

Salient findings are summarized below:

1. The number of calendar days required for attaining the physiological maturity of the cultivars Shahabhazi and US 323, CR Dhan 202, US-395 and Arize 6444 in the section of early, mid early, medium and mid late cultivars, respectively was 100, 100, 108, 132 and 143 days, respectively in the 0 kPa moisture regime. Negligible differences were observed (0-3 days) for attaining physiological maturity even under 40 kPa moisture regime.
2. Higher number of tiller m⁻² was reported from Shahabhazi and US-323 among the early duration cultivars, CR Dhan 202 among the mid early duration cultivars, US-395 among the medium duration cultivars and Arize 6444 among the mid late duration cultivars in both the range of moisture regime.

3. The leaf area index gradually increased up to 60 DAS in early duration cultivars and up to 75 DAS in the rest group of cultivars. The differences in leaf area index in two different moisture regimes were not so appreciable in Shahabhagi and US 323 from early group, CR Dhan 202 from mid early group, US 395 from medium group and Arize 6444 from the mid late group.
4. The canopy temperature of all the cultivars were less than the ambient temperature in the 0 kPa moisture regime. Shahabhagi and US-323 from early group, CR Dhan 202 from mid early group, US 395 from medium group and Arize 6444 from mid-late group were able to maintain the canopy temperature less than the ambient temperature even in moisture stress condition while in rest of the cultivars the canopy temperature was reported to be more than the ambient temperature in the stressed moisture regime.
5. The NDVI values of the cultivars Shahabhagi, US-323, CR Dhan 202, US-395 and Arize 6444 in the 40 kPa moisture regime were statistically at par with the corresponding NDVI values obtained in the 0 kPa moisture regime. The rest cultivars exhibited well marked difference in NDVI values in the stressed moisture regime in comparison to the non stressed moisture regime.
6. Considerable difference in length of panicle was noted due to varieties along with well marked difference in panicle length of the same varieties in different moisture regimes. The maximum panicle length of 30.0 cm and 28.70 cm was recorded in cultivar Arize 6444 under 0 kPa and 40 kPa moisture regime, respectively.
7. Pronounced differences were observed in number of filled grains in different moisture regimes. The highest filled grains panicle⁻¹ was recorded in the cultivar Shahabhagi (114) under 40 kPa moisture regime.
8. The highest test weight was recorded in the cultivar Arize 6444 in both the moisture regimes (26.5 gm in 0 kPa and 26.1 gm in 40 kPa) and the lightest grains were noticed with test weight of 21.0 and 18.8 gm in cultivar Mandakini under 0 and 40 kPa moisture regimes, respectively.

9. Shahabhagi, US-323, CR Dhan 202, US-395 and Arize 6444 recorded grain yield of 4.2 t ha⁻¹, 4.5 t ha⁻¹, 4.0 t ha⁻¹, 7.0 t ha⁻¹ and 6.9 t ha⁻¹, respectively in the 0 kPa moisture regime that is found to be statistically at par with the grain yield noted from these cultivars in the 40 kPa moisture regime.
10. In the non stressed moisture regime, the early duration, mid early duration, medium duration and mid late duration cultivars required 12, 14, 16 and 18 number of irrigations respectively during the entire period of crop growth. However, under stressed condition the respective group of varieties required 4 irrigations (i.e. 8, 10, 12 and 14 numbers).
11. Cultivars Shahabhagi, US-323, CR Dhan 202, US-395 and Arize 6444 were found to be more remunerative with highest net return of Rupees 15,825/-, 20,160/-, 17,326/-, 23,652/- and 23,328/- respectively and B:C ratio of 1.64, 1.80, 1.66, 1.81, 1.72, respectively, in their corresponding duration groups.

CONCLUSION

- 1) Shahabhagi, US-323, CR Dhan 202, US-395 and Arize 6444 required almost the similar number of calendar days in both the moisture regimes for attaining physiological maturity which underlines the fact that there was no sign of forced maturity in these cultivars even in the moisture stress condition. This clearly indicates the fact that these cultivars are stress tolerant cultivars in their respective duration groups.
- 2) Shahabhagi, US-323, CR Dhan 202, US-395 and Arize 6444 recorded grain yield of 4.0 t ha⁻¹, 4.2 t ha⁻¹, 3.8 t ha⁻¹, 7.0 t ha⁻¹ and 6.7 t ha⁻¹, respectively in the 40 kPa moisture regime which was reported to be the highest grain yield in their respective duration groups.
- 3) The early duration, mid early duration, medium duration and mid late duration cultivars required 12 (60 cm), 14 (70 cm), 16(80 cm) and 18 (90 cm) number of irrigations respectively in the 0 kPa moisture regime, as against 8, 10, 12 and 14 numbers of irrigation in respective groups with savings of almost 200 mm of water.

- 4) Cultivars Shahabhazi, US-323, CR Dhan 202, US-395 and Arize 6444 were found to be more remunerative with highest net return of ₹ 15,825/-, 20,160/-, 17,326/-, 23,652/- and 23,328/- respectively and B:C ratio of 1.64, 1.80, 1.66, 1.81, 1.72, respectively, in their corresponding duration groups.

Cultivars like Shahabhazi, US-323, DRR Dhan 43, US-359, ADV-1417 in the early duration cultivars, CR Dhan 202, CR Dhan 201, Naveen amidst the mid early duration cultivars, Ajay, Rajlaxmi, Arize 6129, US 366 among the medium duration cultivars and Arize Prima and Arize 6444 among the mid late cultivars performed well in the areas where there was no scarcity of irrigation water. However, under limited conditions of water Shahabhazi, US-323 among the early duration cultivars, CR Dhan 202 among the mid early duration cultivars, US 395 among the medium duration cultivars and Arize 6444 among the mid late cultivars recorded higher yield than the corresponding counterparts.



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APPENDICES

Appendix I GDD- Growing Degree Days

DATE	Tmax (°C)	Tmin (°C)	Tmean (°C)	Tbase (°C)	Tmean-Tbase	GDD
15.01.2015	27.3	13.5	20.4	10	10.4	10.4
16.01.2015	27.1	13.2	20.15	10	10.15	20.55
17.01.2015	27.3	11.8	19.55	10	9.55	30.1
18.01.2015	18	12	15	10	5	35.1
19.01.2015	27.2	10.6	18.9	10	8.9	44
20.01.2015	27	11	19	10	9	53
21.01.2015	25.8	10.6	18.2	10	8.2	61.2
22.01.2015	27	9.6	18.3	10	8.3	69.5
23.01.2015	29.1	10.6	19.85	10	9.85	79.35
24.01.2015	29.8	12.7	21.25	10	11.25	90.6
25.01.2015	30	13.6	21.8	10	11.8	102.4
26.01.2015	30.3	15.3	22.8	10	12.8	115.2
27.01.2015	30.8	16.4	23.6	10	13.6	128.8
28.01.2015	30.5	16.2	23.35	10	13.35	142.15
29.01.2015	30.6	16.4	23.5	10	13.5	155.65
30.01.2015	31.5	17.7	24.6	10	14.6	170.25
31.01.2015	28.4	15.2	21.8	10	11.8	182.05
1.02.2015	27	13.2	20.1	10	10.1	192.15
2.02.2015	27.4	13.6	20.5	10	10.5	202.65
3.02.2015	29	12.8	20.9	10	10.9	213.55
4.02.2015	30	12.6	21.3	10	11.3	224.85
5.02.2015	32.2	13.2	22.7	10	12.7	237.55
6.02.2015	32	15.6	23.8	10	13.8	251.35
7.02.2015	31	14.6	22.8	10	12.8	264.15
8.02.2015	30.6	16	23.3	10	13.3	277.45
9.02.2015	31	14.4	22.7	10	12.7	290.15
10.02.2015	30.8	15.6	23.2	10	13.2	303.35
11.02.2015	31.4	16.8	24.1	10	14.1	317.45
12.02.2015	31	16.2	23.6	10	13.6	331.05
13.02.2015	31.4	15	23.2	10	13.2	344.25
14.02.2015	30.4	16	23.2	10	13.2	357.45
15.02.2015	31.8	16.6	24.2	10	14.2	371.65
16.02.2015	33	17.2	25.1	10	15.1	386.75
17.02.2015	32	20.2	26.1	10	16.1	402.85
18.02.2015	33	20.6	26.8	10	16.8	419.65
19.02.2015	33.2	21.4	27.3	10	17.3	436.95
20.02.2015	34.8	20.8	27.8	10	17.8	454.75
21.02.2015	34.5	20.1	27.3	10	17.3	472.05
22.02.2015	34	18.6	26.3	10	16.3	488.35
23.02.2015	36	18	27	10	17	505.35
24.02.2015	36.8	17.6	27.2	10	17.2	522.55
25.02.2015	37	18.4	27.7	10	17.7	540.25
26.02.2015	36.1	20.6	28.35	10	18.35	558.6
27.02.2015	36	21.4	28.7	10	18.7	577.3
28.02.2015	35.8	19.4	27.6	10	17.6	594.9
1.03.2015	35	18	26.5	10	16.5	611.4
2.03.2015	35.2	35.4	35.3	10	25.3	636.7
3.03.2015	35.4	22	28.7	10	18.7	655.4
4.03.2015	36.3	21.6	28.95	10	18.95	674.35
5.03.2015	35	21	28	10	18	692.35

DATE	Tmax (°C)	Tmin (°C)	Tmean (°C)	Tbase (°C)	Tmean-Tbase	GDD
6.03.2015	33.7	18.2	25.95	10	15.95	708.3
7.03.2015	33.2	21	27.1	10	17.1	725.4
8.03.2015	34	19.2	26.6	10	16.6	742
9.03.2015	34.2	20	27.1	10	17.1	759.1
10.03.2015	35.6	19	27.3	10	17.3	776.4
11.03.2015	37.1	20.3	28.7	10	18.7	795.1
12.03.2015	36.6	19.2	27.9	10	17.9	813
13.03.2015	37	21.4	29.2	10	19.2	832.2
14.03.2015	35.2	21.4	28.3	10	18.3	850.5
15.03.2015	37	22.4	29.7	10	19.7	870.2
16.03.2015	38.6	21.8	30.2	10	20.2	890.4
17.03.2015	34.5	19.5	27	10	17	907.4
18.03.2015	37	22.2	29.6	10	19.6	927
19.03.2015	36	20.2	28.1	10	18.1	945.1
20.03.2015	33.6	21.4	27.5	10	17.5	962.6
21.03.2015	34.6	26.2	30.4	10	20.4	983
22.03.2015	37.2	23.6	30.4	10	20.4	1003.4
23.03.2015	37.6	22.2	29.9	10	19.9	1023.3
24.03.2015	37.8	24.5	31.15	10	21.15	1044.45
25.03.2015	37.6	24.2	30.9	10	20.9	1065.35
26.03.2015	36	24	30	10	20	1085.35
27.03.2015	35.6	23	29.3	10	19.3	1104.65
28.03.2015	36	23.6	29.8	10	19.8	1124.45
29.03.2015	35.6	18.6	27.1	10	17.1	1141.55
30.03.2015	36	24	30	10	20	1161.55
31.03.2015	36	23.2	29.6	10	19.6	1181.15
1.04.2015	37.8	24	30.9	10	20.9	1202.05
2.04.2015	38.7	26	32.35	10	22.35	1224.4
3.04.2015	39.3	22.6	30.95	10	20.95	1245.35
4.04.2015	39.6	25.4	32.5	10	22.5	1267.85
5.04.2015	37.8	24.3	31.05	10	21.05	1288.9
6.04.2015	36	25.8	30.9	10	20.9	1309.8
7.04.2015	36.2	26.2	31.2	10	21.2	1331
8.04.2015	35	25.3	30.15	10	20.15	1351.15
9.04.2015	35.8	23.4	29.6	10	19.6	1370.75
10.04.2015	37.2	24.3	30.75	10	20.75	1391.5
11.04.2015	38	25.2	31.6	10	21.6	1413.1
12.04.2015	38.3	22.8	30.55	10	20.55	1433.65
13.04.2015	33	22.6	27.8	10	17.8	1451.45
14.04.2015	33.2	22.4	27.8	10	17.8	1469.25
15.04.2015	35.8	22.8	29.3	10	19.3	1488.55
16.04.2015	36	23	29.5	10	19.5	1508.05
17.04.2015	35	24.2	29.6	10	19.6	1527.65
18.04.2015	37.6	24.6	31.1	10	21.1	1548.75
19.04.2015	40	26	33	10	23	1571.75
20.04.2015	39.8	26.8	33.3	10	23.3	1595.05
21.04.2015	39.6	26.2	32.9	10	22.9	1617.95
22.04.2015	40.5	22.5	31.5	10	21.5	1639.45
23.04.2015	38.8	25.6	32.2	10	22.2	1661.65
24.04.2015	40.1	24.4	32.25	10	22.25	1683.9
25.04.2015	37	25.8	31.4	10	21.4	1705.3
26.04.2015	37.2	20.4	28.8	10	18.8	1724.1
27.04.2015	32.8	23.8	28.3	10	18.3	1742.4
28.04.2015	35.2	24.2	29.7	10	19.7	1762.1
29.04.2015	36.8	20	28.4	10	18.4	1780.5
30.04.2015	35.2	24.6	29.9	10	19.9	1800.4

DATE	Tmax (°C)	Tmin (°C)	Tmean (°C)	Tbase (°C)	Tmean-Tbase	GDD
01.05.2015	36	24.4	30.2	10	20.2	1820.6
02.05.2015	37.4	24.5	30.95	10	20.95	1841.55
03.05.2015	36.8	25.8	31.3	10	21.3	1862.85
04.05.2015	37	24.8	30.9	10	20.9	1883.75
05.05.2015	36.4	26.8	31.6	10	21.6	1905.35
06.05.2015	37.1	26	31.55	10	21.55	1926.9
07.05.2015	39	25.4	32.2	10	22.2	1949.1
08.05.2015	39.8	26.2	33	10	23	1972.1
09.05.2015	39.4	27.8	33.6	10	23.6	1995.7
10.05.2015	39	27.2	33.1	10	23.1	2018.8
11.05.2015	34.1	27.5	30.8	10	20.8	2039.6
12.05.2015	39	21.8	30.4	10	20.4	2060
13.05.2015	36.8	27.4	32.1	10	22.1	2082.1
14.05.2015	37	25	31	10	21	2103.1
15.05.2015	38.4	27.2	32.8	10	22.8	2125.9
16.05.2015	38.8	26.4	32.6	10	22.6	2148.5
17.05.2015	39	24.6	31.8	10	21.8	2170.3
18.05.2015	38	25.8	31.9	10	21.9	2192.2
19.05.2015	38.5	27.8	33.15	10	23.15	2215.35
20.05.2015	40.2	29	34.6	10	24.6	2239.95
21.05.2015	40.8	29	34.9	10	24.9	2264.85
22.05.2015	40.8	29.4	35.1	10	25.1	2289.95
23.05.2015	40.6	29	34.8	10	24.8	2314.75
24.05.2015	42.5	29.2	35.85	10	25.85	2340.6
25.05.2015	44.8	28.4	36.6	10	26.6	2367.2
26.05.2015	45.2	29.2	37.2	10	27.2	2394.4
27.05.2015	39.5	29.2	34.35	10	24.35	2418.75
28.05.2015	38.6	28.4	33.5	10	23.5	2442.25
29.05.2015	39.6	28.8	34.2	10	24.2	2466.45
30.05.2015	38.8	28.2	33.5	10	23.5	2489.95
31.05.2015	39.2	28	33.6	10	23.6	2513.55
01.06.2015	40	28.5	34.25	10	24.25	2537.8
02.06.2015	38.6	27	32.8	10	22.8	2560.6
03.06.2015	41.2	26	33.6	10	23.6	2584.2
04.06.2015	38	29.4	33.7	10	23.7	2607.9
05.06.2015	36.8	26.8	31.8	10	21.8	2629.7
06.06.2015	37.5	29	33.25	10	23.25	2652.95
07.06.2015	39.2	28.3	33.75	10	23.75	2676.7
08.06.2015	37.6	27.5	32.55	10	22.55	2699.25

Appendix -II Calculation of scale of finance and estimation of yield

Early Rice

Components of Cost

(Per Ha)

		Unit/MD	Cost (Rs)
A	Labour		
1	Tractor ploughing and puddling @Rs. 425/Hr	8 Hrs	3400
2	Tractor for carrying and threshing @Rs. 425/Hrs	3 Hrs	1275
3	Cleaning field and bunds @ Rs. 92.50/ MD.	5 MD	463
4	Application of compost & basal fertilizers	5 MD	463
5	Seed treatment, sowing	2 MD	185
6	Beusaning with bullock plough @ Rs.225/day	5 Nos.	1125
7	Hand weeding	25 MD	2313
8	Application of PP chemicals and weedicide	8 MD	740
9	Application of fertilizers	2 MD	185
10	Cutting, bunding, loading and unloading	33 MD	3053
11	Threshing, Winnowing, Bagging, Storing	20 MD	1850
	Sub-Total A	95 MD	15052
B	Inputs		
1	Cost of Seeds @18.30 /kg	75 Kg	1373
2.	Seed treating chemicals @ 3 g /kg & Rs.0.6/ g.	225 g	135
3	Cost of Mannure @Rs 600 /MT	5 MT	3000
4	Cost of Fertilizer		
	N (In shape of Urea) @Rs. 12.12/ Kg	40 Kg	485
	P2 O5(In shape of DAP) @Rs. 40.92/ Kg	20 Kg	818
	K2O(In shape of MOP) @Rs. 19.58/ Kg	20 Kg	392
5	Micronutrient		250
6	Cost of PP Chemicals @Rs. 600 /No	2 Nos	1200
7	Cost of Weedicide @Rs 500 /Kg ai	1 Kg	500
	Sub-Total B		8153
1	Miscellaneous/ Contingency @ 10%		2321
	Grand Total cost of cost		25526
	Projected Yield and income		
1	Grain yield (q/ha)		
2	Straw yield (q/ha)		
	Income from grain @ RS 1410 per quintal		
	Income from straw @ RS 70 per quintal		
	Total Income		
	Net Income(Total Income-Total cost)		

Mid early Rice

Components of Cost		(Per Ha)	
		Unit/MD	Cost (Rs)
A	Labour		
1	Tractor ploughing and puddling @Rs. 425/Hr	8 Hrs	3400
2	Tractor for carrying and threshing @Rs. 425/Hrs	3 Hrs	1275
3	Cleaning field and bunds @ Rs. 92.50/ MD.	5 MD	463
4	Application of compost & basal fertilizers	5 MD	463
5	Seed treatment, sowing	2 MD	185
6	Beusaning with bullock plough @ Rs.225/day	5 Nos.	1125
7	Hand weeding	25 MD	2313
8	Disgrouping	15 MD	1388
9	Application of PP chemicals and weedicide	8 MD	740
10	Application of fertilizers	2 MD	185
11	Cutting, bunding, loading and unloading	33 MD	3053
12	Threshing, Winnowing, Bagging, Storing	20 MD	1850
	Sub-Total A	95 MD	16440
B	Inputs		
1	Cost of Seeds @18.30 /kg	75 Kg	1373
2.	Seed treating chemicals @ 3 g /kg & Rs.0.6/ g.	225 g	135
3	Cost of Mannure @Rs 600 /MT	5 MT	3000
4	Cost of Fertilizer		
	N (In shape of Urea) @Rs. 12.12/ Kg	40 Kg	485
	P2 O5(In shape of DAP) @Rs. 40.92/ Kg	20 Kg	818
	K2O(In shape of MOP) @Rs. 19.58/ Kg	20 Kg	392
5	Micronutrient		250
6	Cost of PP Chemicals @Rs. 600 /No	2 Nos	1200
7	Cost of Weedicide @Rs 500 /Kg ai	1 Kg	500
	Sub-Total B		8153
1	Miscellaneous/ Contingency @ 10%		2459
	Grand Total cost of cost		27052
	Projected Yield and income		
1	Grain yield (q/ha)		
2	Straw yield (q/ha)		
	Income from grain @ RS 1410 per quintal		
	Income from straw @ RS 70 per quintal		
	Total Income		
	Net Income(Total Income-Total cost)		

Medium Rice

Components of Cost		(Per Ha)	
		Unit/MD	Cost (Rs)
A	Labour		
1	Tractor ploughing and puddling @Rs. 425/Hr	10 Hrs	4250
2	Tractor for carrying and threshing @Rs. 425/Hrs	4 Hrs	1700
3	Cleaning field and bunds @ Rs. 92.50/ MD.	5 MD	463
4	Application of compost & basal fertilizers	5 MD	463
5	Bullock ploughing for nursery @ Rs.225/day	1 No.	225
6	Seed treatment, sowing and nursery management	3 MD	278
7	Uprootin, washing, treatment, carry and transplanting	50 MD	4625
8	Hand weeding	20 MD	1850
9	Application of PP chemicals and weedicide	10 MD	925
10	Irrigation (need based)	2 MD	185
11	Application of fertilizers	2 MD	185
12	Cutting, bunding, loading and unloading	45 MD	4163
13	Bunding, loading and unloading of straw	16 MD	1480
14	Threshing, Winnowing, Bagging, Storing	27 MD	2498
	Sub-Total A	185 MD	23290
B	Inputs		
1	Cost of Seeds @18.30 /kg	60 Kg	1098
2.	Seed treating chemicals @ 3 g/kg & Rs.0.6/ g.	180 g	108
3	Cost of Mannure @Rs 600 /MT	5 MT	3000
4	Cost of Fertilizer		
	N (In shape of Urea) @Rs. 12.12/ Kg	80 Kg	970
	P2 O5(In shape of DAP) @Rs. 40.92/ Kg	40 Kg	1637
	K2O(In shape of MOP) @Rs. 19.58/ Kg	40 Kg	783
5	Micronutrient		250
6	Cost of PP Chemicals @Rs. 600 /No	4 Nos	2400
7	Cost of Weedicide @Rs 500 /Kg ai	1 Kg	500
8	Irrigation charges @Rs.400/irrigation	3 Nos.	1200
	Sub-Total B		11946
1	Miscellaneous/ Contingency @ 10%		
	Grand Total cost of cost		35236
	Projected Yield and income		
1	Grain yield (q/ha)		
2	Straw yield (q/ha)		
	Income from grain @ RS 1410 per quintal		
	Income from straw @ RS 70 per quintal		
	Total Income		
	Net Income(Total Income-Total cost)		

Mid late Rice

Components of Cost		(Per Ha)	
		Unit/MD	Cost (Rs)
A	Labour		
1	Tractor ploughing and puddling @Rs. 425/Hr	10 Hrs	4250
2	Tractor for carrying and threshing @Rs. 425/Hrs	4 Hrs	1700
3	Cleaning field and bunds @ Rs. 92.50/ MD.	5 MD	463
4	Application of compost & basal fertilizers	5 MD	463
5	Bullock ploughing for nursery @ Rs.225/day	1 No.	225
6	Seed treatment, sowing and nursery management	3 MD	278
7	Uprootin, washing, treatment, carry and transplanting	50 MD	4625
8	Hand weeding	20 MD	1850
9	Application of PP chemicals and weedicide	10 MD	925
10	Irrigation (need based)	2 MD	185
11	Application of fertilizers	2 MD	185
12	Cutting, bunding, loading and unloading	45 MD	4163
13	Bunding, loading and unloading of straw	16 MD	1480
14	Threshing, Winnowing, Bagging, Storing	27 MD	2498
	Sub-Total A	185 MD	23290
B	Inputs		
1	Cost of Seeds @18.30 /kg	60 Kg	1098
2.	Seed treating chemicals @ 3 g /kg & Rs.0.6/ g.	180 g	108
3	Cost of Mannure @Rs 600 /MT	5 MT	3000
4	Cost of Fertilizer		
	N (In shape of Urea) @Rs. 12.12/ Kg	80 Kg	970
	P2 O5(In shape of DAP) @Rs. 40.92/ Kg	40 Kg	1637
	K2O(In shape of MOP) @Rs. 19.58/ Kg	40 Kg	783
5	Micronutrient		250
6	Cost of PP Chemicals @Rs. 600 /No	4 Nos	2400
7	Cost of Weedicide @Rs 500 /Kg ai	1 Kg	500
8	Irrigation charges @Rs.400/irrigation	3 Nos.	1200
	Sub-Total B		11946
1	Miscellaneous/ Contingency @ 10%		3524
	Grand Total cost of cost		38760
	Projected Yield and income		
1	Grain yield (q/ha)		
2	Straw yield (q/ha)		
	Income from grain @ RS 1410 per quintal		
	Income from straw @ RS 70 per quintal		
	Total Income		
	Net Income(Total Income-Total cost)		

