Impact of Climate Resilient Technology on Growth and Yield of Paddy (*Oryza Sativa* L.) under Submergence Condition

Abstract

The submergence of rice fields is a significant issue in India's rice production, which is further aggravated by the unpredictable monsoon rain patterns and the impact of climate change. Larger variation in rainfall patterns affected by the timing of nursery raising and transplanting later in the main field therefore, we adopted Climate Resilient Technology (CRT) for rice production, Extended seedbed durations for rice seedlings allow for adequate rainfall during the monsoon season. So that the experiment was conducted at 30 farmer's fields of NICRA village, Khana Bari, Kishanganj, Bihar, India, in 2022 under the supervision farm science Center, Kishanganj, the experiment was framed in randomized block design with ten replications. All plots received the recommended dose of fertilizers (120:60:40 kg ha^{-1} N.P.K.) in equal amounts. Urea, di-ammonium phosphate, and muriate of potash were used as the sources of nitrogen, phosphorus, and potassium, respectively. To determine the growth characters i.e., plant height (cm) at harvest stage, number of effective tillers $hill^{-1}$, LAI, Chlorophyll concentration (SPAD) and days to 50 per cent flowering were recorded at 90 days. Yield attributes *viz*., After the completion of the harvest, various observations were recorded, such as the number of panicles/m^2, the number of grains per panicle, the number of filled and unfilled grains per panicle, the test weight in grams, and the yield. This encompassed grain yield, straw yield, biological yield in quintals per hectare, and harvest index percentage. During the field experiment, both the climate-resilient technology Swarna Sub1 and Sabour Sampans paddy varieties were tested. Swarna Sub1 was found to be significantly superior in terms of plant growth, yield attributes, and yield characteristics. under submergence conditions. The significant maximum grain yield (48 q ha^{-1}), straw yield (84 q ha^{-1}), biological yield (153 q ha^{-1}), and harvest index (45%) were recorded in Swarna Sub-1.

Key word: Submergence, CRT, NICRA, LAI, SPAD, biological yield, Harvest index.

1. INTRODUCTION

Rice is an important food crop worldwide, with significant economic and social importance to many people. Rice fields extend over the production of this crop, covering 160 million hectares, which is more than any other crop. This makes it the most important food production system on the planet. Rice is grown in more than 100 countries around the world and is ranked third in global production, with 493 million tonnes (FAOSTAT; 2010). Most rice is cultivated in lowland areas through irrigation or rain in the major countries that produce rice. Irrigated rice occupies 78% of the overall rice-harvested region, mainly focusing on alluvial flood zones and deltas in the humid and sub-humid tropics of Asia, according to (Pathak et al. 2018). Change resulting from human activities poses a major challenge to rice production. This poses a direct threat to our essential food and water supplies and indirectly threatens global food security. The rise in carbon dioxide and other greenhouse gases, such as methane and nitrous oxide, in the atmosphere can impact hydrological systems. This results in global warming, which has significant implications for the management of water resources. The agricultural sector is a major consumer of freshwater, accounting for 85% of the total usage. While the impact of climate change on water resources in the future remains uncertain, there has been a rise in the frequency of severe weather conditions, such as floods, leading to abiotic stress. Rice is a predominant food crop of India and Over 80% of the available freshwater resources are utilized for irrigation, with almost half of this amount being allocated for rice cultivation. To produce a one-kilogram grain of rice, farmers have to supply two to three times more water in rice fields than other cereals. The rapid depletion of water resources poses a major threat to the sustainability of irrigated rice, as well as the food security and livelihoods of rice producers and consumers. (Tuong *et al.,* 2004; Mallappa *et al.,* 2021).

The extensive impact of climate change on agriculture can be observed through the significant changes in livestock production, farmer and consumer livelihoods, and the intricate balance between soil, crops, and the atmosphere. Crop production is one of the sectors that are most vulnerable to the effects of climate change, which include higher temperatures, alterations in weather patterns, and increased levels of CO2. Undoubtedly, climate change has significantly impacted crop growth, production, and yield globally, both directly and indirectly, over the last few decades. (Anonymous, 2016). Climate change is causing extreme weather events that result in abiotic stresses such as floods and salinity stress. Gautam *et al.* (2019) have reported that the detrimental impact of these factors on rice production is significant. It has been revealed through research that alterations in temperature and rainfall patterns in India could lead to a decrease of 15-25% in the mean rice yield. (Geethalakshmi *et al.* 2011; Mondal *et al.,* 2015).

It is crucial to recognize the potential for encountering severe weather events such as strong storms, floods, and droughts, despite the difficulty in forecasting rainfall patterns for the latter half of the century. These events are expected to occur more frequently and with greater intensity. (Palanisami, 2017). A study conducted on the impact of climate change on rice production in India revealed that by the end of this century, there will be a 10% reduction in rice yields. Similarly, Singh *et al.* (2010). According to Welch *et al.* (2010), increasing the temperature by 2.5 °C during the vegetative and reproductive stages of rice growth led to a decrease in grain yield by 23% and 27%, respectively. Submergence rice is a type of semi-aquatic plant that can tolerate partial submergence better than other cereals. However, if fully submerged, the plant will die within a few days. These plants are grown in both natural and artificial environments, where submergence stress is a common environmental challenge. Heavy rainfalls in the kharif season have the potential to damage crops in both rainfed and irrigated lowland areas by obstructing drainage and causing extreme rainfall, resulting in submergence. Heavy rainfalls in the kharif season have the potential to damage crops in both rainfed and irrigated lowland areas by obstructing drainage and causing extreme rainfall, resulting in submergence. In South Asia, the yearly average rice yield loss due to submergence is approximately 80 kg per hectare (Dey and Upadhaya, 1996). In South Asia, rice production is significantly impacted by flooding, which is the third most significant abiotic stress after drought. (Widomski and O'Toole, 1990). The heavy rainfall and overflowing rivers have led to flooding; Floods in India have caused a decline in rice production across multiple regions. A staggering 49.8 million hectares, or 12.3% of the total geographical area, have been damaged by floods, as reported by NRAA in 2013. The effects of flooding can vary depending on factors such as plant genotype, pre-treatments of the pants, and intensity of the flooding, these effects are dynamic and can change over time. (Setter *et al.*, 1987). Usually, rice crops are damaged by two types of flooding: flash flooding, which completely inundates the crop for a short time (1-2 weeks), and stagnant flooding, which lasts for several months and causes water to stagnate. During the vegetative growth stage of a crop, if it is fully submerged, the chances of survival are extremely low. Flooding and submergence affect rice yields in various ways. However, rice crops are capable of surviving in submerged conditions due to their ability to germinate seeds in anaerobic conditions, some plants can rapidly grow stems to keep their apical portions above rising water. However, rice plants cannot survive complete inundation for more than a few days due to reduced oxygen levels. Rice plants cannot survive prolonged periods of complete inundation due to reduced oxygen levels that limit respiration and decreased carbon dioxide levels that affect photosynthesis. As a result, rice plants extend their leaves and stems to avoid submergence during floods. Rice plants cannot survive prolonged periods of complete inundation due to reduced oxygen levels that limit respiration and decreased carbon dioxide levels that affect photosynthesis. As a result, rice plants extend their leaves and stems to avoid submergence during floods. During floods, rice plants extend their leaves and stems to prevent submergence. However, this can result in limited respiration and reduced carbon dioxide levels, which negatively affect photosynthesis. This issue is particularly prevalent in deepwater rice varieties which are more capable of coping with flooding than modern high-yielding varieties. When floods persist for several days, the latter cannot elongate fast enough, causing the rice plants to expend more energy trying to stay above the water's surface. As a result, they struggle to recover. (Shahid *et al*., 2021). The Sub 1 introgression lines exhibited exceptional survival rates and improved yield performance when compared with fully submerged, which crucial to the variations. The survival rates of Sub 1 lines were significantly higher than non-Sub 1 lines for over 14 days. Additionally, tolerant Sub 1 lines displayed a faster recovery after submergence, resulting in the production of more new leaves and early tillers. The success of crop varieties that contain the ability of plants to survive underwater for long periods is attributed to their SUB 1 gene. They use a strategy of quiescence to conserve energy while submerged and resume growth once the floodwaters recede. This information is supported by studies conducted by (Bailly-Serres et al. 2010 and Sarkar *et al.* 2006). These crops have demonstrated exceptional performance in contrast to conventional variants, exhibiting greater yields and superior grain quality. Furthermore, they exhibit remarkable resilience in adverse conditions of submergence.

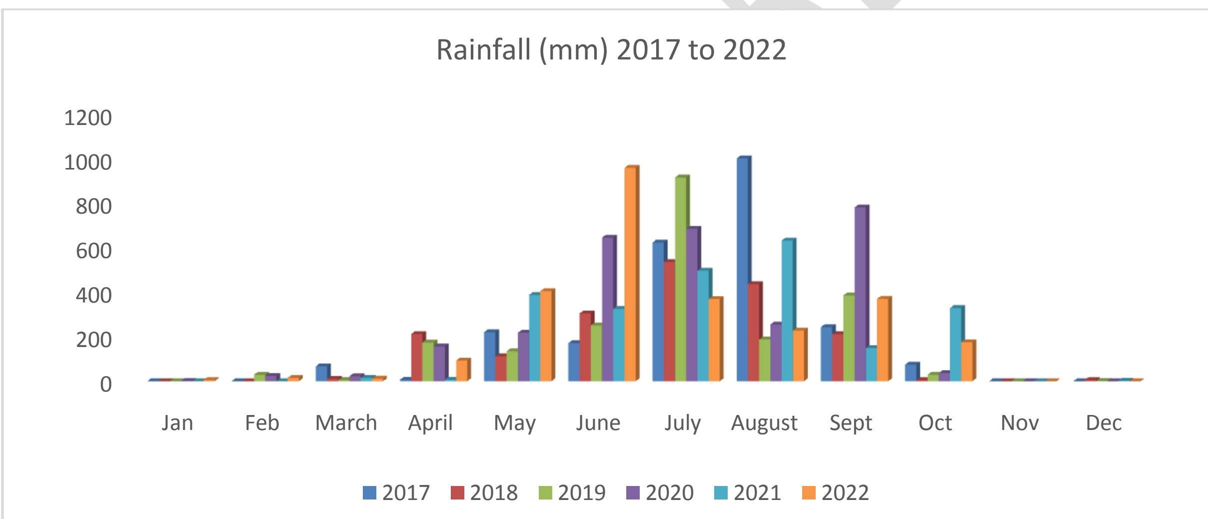
2. MATERIALS AND METHODS

The experiment was conducted in a randomized block design with ten replications. Three Paddy varieties viz., T_0: Control (BB 11), T_1: (Swarna sub-1) T_3 Sabour Sampann at 30 farmer's fields of NICRA village, Khanabari, under the supervision of Farm Science Centre, Kishanganj, Bihar, India during 2022. Comprising 30 plots at different locations. The agro-climatic condition remains similar among the plots. Demonstration of paddy varieties for determining the growth and yield under submergence conditions. Before sowing, of seed was treated with vitavax @ 2g per kilogram of seed the recommended dose of 120 kg N 60 kg P_2O_5 and 40 kg K_2O ha^{-1} was applied through urea (NH_2CONH_2), di-ammonium phosphate (DAP), and muriate of potash (KCL) respectively. To determine the growth parameter viz., at the harvest stage, the height of the plants in cm and the number of effective tillers per hill, LAI, Chlorophyll concentration (SPAD), and days to 50 per cent flowering were recorded at 90 days. After the harvest, various attributes such as the number of panicles/m^2, the number of grains per panicle, the number of filled and unfilled grains per panicle, test weight in grams, and yield including grain yield, straw yield, biological yield in quintal per hectare, and harvest index percentage were recorded. Additionally, the SPAD 502, a handheld chlorophyll meter, also known as a SPAD meter, was used. (Minolta Corporation, Ramsey, NJ) This is a method for quickly and non-destructively estimating the amount of extractable chlorophyll in leaves. (Earl and Tollenaar, 1997). Five plants were selected from each penultimate row for treatment, and their leaves were measured using a leaf-area meter (Systronics 211) to estimate leaf area. The leaf area index was then calculated using a specific formula. suggested by Radford; (1967).

$$LAI = \text{Leaf area}/\text{Ground area}$$

2.2 2Climate and Rainfall

Kishanganj is a district that has a humid climate. It experiences winter from November to February, with January being the coldest month. During this time, temperatures range from 5-10°C, and the maximum temperature ranges from 32-41°C. This district receives an average annual rainfall of 2355 mm, and it's known as the "Cherapunji of Bihar" because of its high rainfall. About 85% of the total rainfall comes from the south-west monsoon, which extends from mid-June to the end of September. The six-year (2017 to 2022) rainfall statistics are given in Graph-1.



Graph: 1. Rainfall (mm) 2017 to 2022, Source: IMD, Pune, 2022

2.3 Statistical analysis

Analyze the data obtained from different observations using the randomized block design procedure and standard ANOVA techniques. We will use the OP STAT computer software program for this analysis. If the F test shows a significance level of 5% ($P < 0.05$), we will calculate the critical difference to determine the significance of differences between the two treatment means.

3. RESULT AND DISCUSSION

3.1 Growth and development

Data pertaining to all growth parameters at various stages of growth under different treatments are presented in Table 1. Plant height, number of effective tillers hill^{-1}, leaf area index (LAI), chlorophyll concentration, and days to 50 per cent flowering were found significantly higher Swarna sub-1 under submergence conditions compared to BB11 and Sabour Sampann. Variety Swarna sub-1 is at par with Sabour sampan in the case of plant height and chlorophyll concentration. The incensement in plant height, the number of effective tillers hill^{-1}, leaf area index, chlorophyll concentration, and days to 50 per cent flowering were to the tune of 17.4, 55.5, 27.7, 20.6, and 14.2 per cent higher as compared to BB-11 In general plant height increased as the advanced in stage and attained its maximum growth at harvest stage. The height of plants is mainly determined by their genotype, but it can also be influenced by the surrounding environmental factors. During the present study, it was noted that Swarna sub -1 recorded maximum plant height (108 cm) at the harvest stage which was at par with Sabour Sampann (98 cm) and significantly superior over the treatment BB-11 (92 cm) at the harvest stage. A similar result was found by Iftekharuddaula *et al.* (2015).

The number of effective tillers per hill was significantly increased by the variety of Swarna sub -1 when grown under submergence conditions. Variety Swarna sub -1 recorded the highest number of effective tillers hill^{-1} (14) it was significantly superior over the rest of the treatments i.e., Sabour Sampann (12) and BB-11 (9) at 90 days Rice plants develop tillers from the leaf axils at every non-elongated node of the main shoot or other tillers during their vegetative growth stage. The number of effective tillers per hill is directly related to the length of the vegetative period and nutrient uptake. Similar studies were also observed by (Baloch *et al.* (2006)

At 90 days after sowing, there was a decrease in LAI across all treatments. This was caused by nutrient depletion in the leaves during the reproductive stage (grain-filling stage), which resulted in leaf senescence. Additionally, cell division and cell expansion are highly affected by moisture stress, and water deficits have a significant impact on leaf area. When these stages experience water stress, it leads to a reduction in leaf area index and, greater effects on growth in the present study significantly highest leaf area index (4.25) was found under Swarna sub -1, according to a study, one treatment was found to be more effective than the others after 90 days. Baloch et al. (2006) also reported similar results.

The chlorophyll concentration highly correlated with the plant's nitrogen status and moisture content in plants maximum chlorophyll concentration (3.45 mg/g) is recorded in Swarna sub -1 It was at par with Sabour Sampann and significantly superior to BB-11. a similar result was found by Ismail *et al.* (2013) and Ell *et al.* (2003)

Days to 50 per cent flowering was influenced by varietal performance under submergence conditions Data shows that the maximum 50 per cent flowering days was found in the Swarna sub 1 variety (112 days) but being at par with Sabour Sampann (105- days) and significantly superior over BB-11 (98- days). Recorded responses that were similar were also noted by Singh *et al.* (2009 and 2011).

Table:1. Variation in growth characters among rice varieties under submergence condition

Treatments	**Plant height** (cm)	**No. of Effective tillers/hill**	**LAI**	**Chlorophyll Concentration (mg/g)**	**Days to 50% flowering**
BB-11	92	9	3.35	2.86	98
Swarna Sub -1	108	14	4.25	3.45	112
Sabour Sampann	98	12	3.83	3.26	105
Sem ±	3.5	0.41	0.13	0.11	3.6
CD (P=0.05)	10.4	1.23	0.40	0.33	11.0

3.2 Yield and Yield Attributes

Data about the yield attributes of rice varieties under submergence conditions are given in Table 2. Swarna sub 1 variety resulted in a significantly higher number of panicle/m^2, number of grain panicle^{-1}, and number of filled grain panicle^{-1} and test weight, respectively, than BB 11 and Sabour Sampann. Number of panicle/m^2 were significantly influenced by treatments. The number of panicle/m^2 was increased in Swarna sub -1 grow under submergence conditions. Variety Swarna sub -1 recorded the highest number of panicle/m^2 (466) it was significantly superior over the rest of the treatments i.e., Sabour Sampann (400) and BB-11(300) at 90 days. Similar results were also recorded by Baloch *et al.* (2006), Gawai *et al.* (2006) and Das and Baruah (2007)

The number of grains panicle^{-1} is an important yield contributing factor of rice, which is significantly influenced by the prevailing growing conditions and genetic potential of a cultivar. The number of grains panicle^{-1} varied significantly among varieties. Swarna sub -1 had a significantly higher number of grains per panicle (74) but was at par with Sabour Sampann (71) and significantly superior to BB-11 similar result was found by Baloch *et al.* (2006), Gawai *et al.* (2006), and Das and Baruah, (2007)

The number of filled and un-filled grains per panicle varied significantly among varieties Swarna sub -1 found a significantly higher number of filled grains per panicle (65) and lowest unfilled grain (9) under submergence conditions. But being at par with Sabour Sampann (60) and significantly higher unfilled grain recorded under BB-11 (11) being at par with Sabour Sampann. The weight of 1000 grains decreased significantly when submerged, from 22.8 g to 20.2 g. Swarna sub -1 (22.8 g) had the highest grain weight and BB-11 (20.2) had the lowest compared with other varieties under submergence conditions.

Table: 2. Variation in yield attributes among rice varieties under submergence condition

Treatment	**No. of panicle/m^2**	**Grains/panicle**	**No. of filled grain/ panicle**	**No. of unfilled grains/panicles**	**Test weight (g)**
BB-11	300	68	57	11	20.5
Swarna Sub -1	466	74	65	9	22.8
Sabour Sampann	400	70	60	10	20.2
Sem ±	14	2.5	2.1	0.35	0.7
CD (P=0.05)	41	7.6	6.4	1.06	2.2

Data associated with all yield parameters of the experimental crop of rice were influenced significantly due to climate resilient technology except harvest index and presented in Table 3. Grain yield is a manifestation of yield contributing characters viz. Number of panicles, number of grains per panicle, and 1000-grain weight. Among three varieties 'Swarna Sub -1' recorded significantly higher yield parameters viz. grain yield (48 q/ha), straw yield (84 q/ha), biological yield (153 q/ha), and harvest index (45%) as compared to rest of treatments which was at par with 'Sabour Sampann' over the rest of treatments but in case of harvest index was found non-significant Yield advantage due to sowing of Swarna sub-1 variety 29.2 and 50 per cent, over 'Sabour Sampann' and 'BB 11' varieties.

The grain yield is determined by a variety of factors, including genetics and the environment. The process of rice yield formation is complex and involves a balance between the source (photosynthesis and availability of nutrients) and the sink (storage organs). In this study, different rice varieties had a significant impact on grain yield, with noticeable differences between each variety. High yield of 'Swarna sub -1' The reason for its higher biomass accumulation seems to be due to a greater number of tillers and leaves, as well as proper partitioning, as shown by a higher harvest index. Additionally, it has good yield attributes, such as panicle length and weight and test weight. In areas prone to coastal flooding, it is important to consider the height of Swarna-Sub1 plants. If the water level stays above the plant canopy for more than two weeks, the plants may not grow properly because the SUB1 gene suppresses elongation. To address this issue, it may be necessary to introduce the SUB1 gene into taller plant types to ensure continued growth in these flood-prone areas. (Septiningsih e*t al.* 2009). So many works are confined that the submergence during reproductive and maturity stages reduces rice quality and yield components, including grain yield, shoot biomass, and harvest index, by significantly delaying flowering and maturity (Marndi *et al*.2022). Introducing the SUB1 gene into well-known varieties did not negatively affect their performance in normal conditions. Instead, it improved their yield and the quality of their grain under submergence (Mackill *et al.* 2012). whereas variety 'BB 11' recorded low grain yield (24 q ha^{-1}) The reason for the lower biomass accumulation could be due to the fewer number of tillers and leaves, as well as its lower test weight. The poor performance of the 'BB 11' variety under submergence conditions. The short variety of plants becomes even shorter when flooded, in contrast to the tall variety. The study findings is consistent with the research conducted by Mackill *et al.* (2012), Ismail *et al.* (2013), and Singh *et al*. (2009). The maximum straw yield was recorded in 'Swarna sub -1' (84 q ha^{-1}) followed by 'Sabour Sampann' (62 q ha^{-1}), respectively. Variety 'Swarna sub -1' was efficient in utilizing biomass towards grain formation, as evidenced by its highest harvest index (45 %). These findings are in close conformity with those of Mackill *et al.* (2012), Ismail *et al.* (2013) and Singh *et al.* (2009).

Biological yield is the total grain yield and straw yield. Significantly more grain yield and stover yield were obtained in 'Swarna sub -1', which caused significantly more biological yield (153 q/ha) than other treatments similar result has been found by Ismail *et al.* (2013) and Singh *et al.* (2009). Singh *et al.* (2014). The harvest index is a measure of a plant's ability to move nutrients from its source organs to its sinks. Variety 'Swarna sub-1' led to higher aboveground biomass, and the number of grains panicle^{-1} was also significantly increased due to higher dry matter accumulation and efficient translocation of photosynthate from source to sink due to higher nitrogen availability observed by Mackill *et al.* (2012) and Singh *et al.* (2009)

Table: 3. Variation in yield parameter among rice varieties under submergence condition

Treatments	Grain yield (q/ha)	Straw yield (q/ha)	Biological yield (q/ha)	Harvest index (HI)
BB-11	24	48	82	42
Swarna sub -1	48	84	153	45
Sabour Sampann	34	62	111	44
Sem ±	1.3	2.3	4.0	1.5
CD (P=0.05)	3.8	6.8	12.0	NS

4. CONCLUSION

Based on the experimental findings, it can be concluded that the Swarna Sub 1 rice variety recorded the maximum growth rate, yield attributes, and yield. Thus ‘Swarna sub1’ variety of rice performed better under submergence conditions than Sabour Sampann’ and BB 11’. Submergence tolerant varieties, developed by the introgression of the SUB 1 gene into mega varieties, therefore, they are not only enhancing flood tolerance but also stabilizing rice productivity in submergence conditions. In general, farmers under submergence conditions use minimal inputs, so the Sub1 varieties are encouraging the farmers to use more inputs to maximize their yield potential.

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