INFLUENCE OF ESTABLISHMENT METHODS ON PERFORMANCE AND ENERGETICS OF *KHARIF* RICE VARIETIES

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ABSTRACT

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| **Aims:** To find out the suitable establishment methods for the performance of different rice varieties of Assam.**Study design:** Split plot design**Place and Duration of Study:** Instructional cum Research Farm, Assam Agricultural University Jorhat, during kharif season of 2022.**Methodology:** The treatments were laid out in a split plot design with three replications. The treatments comprised of four methods of establishment in main plots *viz.,* M1: Dry broadcasting in unpuddled soil, turned line sown crop by self-propelled, M2: Broadcasting of pre germinated seeds in puddled soil, turned line sown crop by self-propelled paddy weeder paddy weeder, M3: Drum seeding in puddled soils. (Wet DSR), M4: Conventional transplanting and sub-plots consisted of four different varieties. i.e., V1: Numali, V2: Shraboni, V3: Dholi and V4: Bina dhan- 11. From the study, the growth, physiological parameters, yield attributes and yield of varieties under different establishment methods were recorded and analyzed.**Results:** All the data pertaining to the present investigation wherever needed were statistically analyzed for split plot design as per the method described by Panse and Sukhatme (1985) known as Analysis of Variance (ANOVA). Critical differences (CD) at 5 per cent probability level was calculated only when the F value has been found to be significant. Results revealed that among the different methods of establishment, conventional transplanting method (M4) recorded significantly higher plant growth and physiological parameters *viz*., plant height, dry matter accumulation, crop growth rate and relative growth rate. In case of different varieties, Numali (V1) recorded significantly higher plant height, number of tillers, dry matter accumulation, relative growth rate at harvest as well as yield attributes including number of panicles per square meter, panicle length, panicle weight, 1000-grain weight, total number of grains per panicle, total number of filled grains per panicle and yield parameters such as grain yield, straw yield and harvest index. The interaction of different methods of establishment and varieties significantly influenced the plant growth, physiology and yield parameters. The variety Numali under conventional transplanting recorded significantly increased plant height, dry matter production, yield attributing characters as well as grain yield straw yield. **Conclusion:** From this study, it was revealed that drum seeding of sprouted seeds in puddled soil (wet-DSR) can be an effective agronomic technique for establishing rice crop for the medium-lowland rice ecosystem of Assam. Adoption of medium duration varieties like Numali or Shraboni is a suitable option for enhancing cropping intensity of Assam for the rice based double cropped areas, as evident from its early maturity. |

***Keywords****: Establishment, Varieties, Rice, Numali, Shraboni, Dholi, Bina*

1. INTRODUCTION

Rice (*Oryza sativa L.)* is one of the major cereal crops grown in more than 100 countries of the world. It is the staple food for almost 60% of the world population. In India rice is grown in varying agro-ecological regimes extending from 79° to 90°E longitude and 16° to 28° N latitude (Anonymous,2020). India grows rice in 43.9 million ha with production of 114.45 million tonnes of rice and average productivity of 2.6 tonnes per ha (Agriculture Statistics at a Glance, 2022). India had the highest export volume of rice worldwide, USD 4796 million (Rs 35448crore) in 2020- 21(Ministry of Commerce and Industry) In Assam rice is grown in an area of 2.3 million ha and account for the production of 4.3 million tonnes in 2021-22 (Statistical Handbook of Assam, 2022).

In the early period, it is believed that when rice was domesticated from its grass species *Oryza* *sativa* or *Oryza glaberrima*, its cultivation was mostly done by dry broadcasting method which is believed to be the oldest method of rice establishment and direct seeding method was followed under shifting cultivation also. But during ’70s in many parts of the world rice cultivation by transplanting method was initiated since availability of both human labour and natural resources were abundant and gradually widespread and became the most dominant and traditional method of establishment of lowland rice. However, due to non-availability of irrigation water for special operations like puddling, shortage of labour during peak period of transplanting, escalating labour cost, uncertainty and scarcity of rain due to delayed onset of monsoon make the transplanting technique uncertain which invariably leads to delay in transplanting often resulting in yield reduction. Due to ever increasing population, the demand for food grain is increasing which necessitates the need for development of alternative establishment methods. The establishment costs associated with farmers' traditional techniques of growing rice in Asian nations are quite high and these approaches not only limit yield and return but also damage the land and increase water usage. Moreover, the main issues that threaten the sustainability of high-water-demanding rice-wheat cropping systems, particularly in South Asian countries, include a rising population, expanding industries, declining rainfall activity, and a labor shortage. Direct-seeded rice (DSR) can be a feasible alternative to conventional puddled transplanted rice because of its potential to save water (30-40 %), minimize labor use by (40-45%) and mitigate climate changes like greenhouse gas (GHG) emission as compare to transplanted rice.

Upland rice is often planted using dry direct seeding, which has been shown to boost grain yield by 22%, save 35–57% of water compared to flooded systems, and achieve above 80% NUE. The wet seeding method of DSR, in which pre-germinated seeds are sown into well-puddled fields either by broadcasting or using a drum seeder, is suited for irrigated areas with reasonably decent amounts of rainfall. It was reported that wet-direct seeded rice and direct seeded aerobic rice resulted in 7.63% and 11.29% and 10.75% and 15.64% in grain yield increments 2015 and 2016, respectively (Singh et al. (2017).

Drum seeding is the practice of directly planting pre-germinated (sprouted) paddy seeds on a field that has been leveled and drained of surplus water using a device called a drum seeder. It typically comprises four drums with hyperbolic shapes and a 20 cm row-to-row spacing that can sow eight lines in one pass. However, improper use of the machinery might cause the perforations in the drum to become clogged, which could result in uneven seed distribution. When seeds are sown in standing water in fields that have been prepared with ridges and furrows before being submerged, water seeding is appropriate for high rainfall areas. The depressions are made to keep the optimal crop geometry and stop the seeds from drifting away. This in-depth study examines the subtleties of Direct Seeding Rice, its methods, advantages, and potential to revolutionize agricultural operations for different varieties.

2. material and methods

**2.1 Experimental site and soil description:**

The experiment was conducted on a sandy loam soil of the Instructional Cum Research (ICR) Farm of Assam Agricultural University, Jorhat. The site is located at 26°47'N latitude, 94°12'E longitude and at an altitude of 86.6 m above the mean sea level. The climatic condition of Jorhat is sub-tropical humid with hot summer and cold winter. The pre-monsoon shower begins from mid-March to April. Monsoon rain in this region generally prevalent from the month of June and persist up to the month of September-October. Average annual rainfall is 2042.0 mm and the rainfall intensity decline from mid of October to January. The total amount of rainfall received during the crop growth period (29th June, 2022–25th November, 2022) was 1024.3 mm of which the highest amount received in the 35th SMW (standard meteorological week) i.e., during 27th August- 2nd September with total rainfall of 104.4 mm. The soil of the experimental site was sandy loam in texture, acidic in nature (pH 5.10), medium in organic carbon content (0.51%), available N (219.52 kg/ha), available P2O5 (22.32 kg/ha) and available K2O (125.64 kg/ha).

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| **Figure 1: Weekly meteorological data during the crop season 2021-2022** |

Soil and climatic conditions exert a crucial influence on enhancing the growth and yield of all crops. Even minor deviations in weather parameters, especially temperature and precipitation, from the established norms can potentially lead to divergent outcomes or detrimental impacts on the growth and development of crops. The meteorological conditions experienced throughout the crop season (Figure-1) exhibited considerable variations in mean weekly temperature, relative humidity and bright sunshine hours. The cultivation period from June to November had received a total rainfall of 1024.3 mm spanning fifty-four (54) rainy days and the daily evaporation recorded during the experiment ranges from 1.8- 3.8 mm per day. Notably, the intensity and frequency of rainfall were relatively higher during the initial stages of the crop growth cycle, as well as during the reproductive phase of crop development occurring in August and September, a distinct absence of rainfall was observed in the latter part of the crop's growth period. The mean weekly maximum temperature ranged from 28.2 to 34.9°C and the minimum temperature ranged from 12.3 to 25.6°C throughout the entire crop growth period. Moreover, the weekly mean relative humidity (RH) ranged from 90 to 99 % in the morning and 51 to 85 % during the evening hours during the entire experiment timeline.

**2.2 Treatment details**:

The treatments combinations are comprised of two factors viz., method of establishment and variety. These are mentioned below along with their notations. The details of treatment combinations are given in Table 1.

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| **Table 1: Treatment combinations** |
| Method of establishment | Variety |
| Numali (V1) | Shraboni(V­2) | Dholi(V3) | Bina Dhan-11 (V4) |
| Dry broadcasting in unpuddled soil, turned line sown crop by self-propelled paddy weeder at 25 cm seedling height (M1) | M1V1 | M1V2 | M1V3 | M1V4 |
| Broadcasting of pre-germinated seeds in puddled soil, turned line sown crop by self-propelled paddy weeder at 25 cm seedling height (M2) | M2V1 | M2V2 | M2V3 | M2V4 |
| Drum seeding in puddled soils. (Wet DSR) (M3) | M3V1 | M3V2 | M3V3 | M3V4 |
| Conventional transplanting (M4) | M4V1 | M4V2 | M4V3 | M4V4 |

**2.3 Description on varietal characters of the test varieties**:

**2.3.1 Numali:** Numali variety evolve by crossing APMS and Piolee of rice was released in the year 2020. It is a medium duration high yielding variety which matures 130-135 days and 22 average yield is around (4.5-5 t/ha).

**2.3.2 Shraboni**: Sharboni was evolve by crossing APMA and Piolee, which was recommended by AAU in 2011. It is a medium duration variety with a duration of 130-135 days. Yield potential is 4.0-4.5 t/ha with multiple resistant to Sheath rot, Neck blast and rice tungro Disease and mild resistance to Green Leaf hopper.

**2.3.3 Dholi**: Dholi was releases in the year 2022. It is suitable for flood prone area with a potential yield of 5-5.5 t/ha. It is also suitable for double cropping.

**2.3.4 Bina Dhan-11**: The variety was a cross of IRRI 149 x Ciherang and was notified in the year 2015. It has the ability to tolerate submergence condition up to 2 weeks, hence, considered as the submergence tolerant variety, or climate resilient variety. Bina dhan-11 is a Sedi dwarf variety of rice with a plant height of 107-115 cm, grains are medium slender and matures in 115-120 days in Sali season but it may extend to 135 days in Boro season suitable for growing in medium or shallow low land. In normal growing condition, the yield of this variety ranges from 5.5 to 6.0 t/ha.

**2.4 Agronomic practices:**

For the Dry Direct Seeded Rice (M1) method, dry seeds were manually broadcast onto unpuddled soil at a seed rate of 100 kg/ha. In the case of pre-germinated Broadcasting (M2), seeds were soaked in water for 24 hours and then incubated in wet gunny bags for 36 hours to facilitate desired sprouting and then the seeds were broadcasted manually on puddled soil. For Drum-Seeded Rice (M3), seeds at a rate of 35 kg/ha were soaked for 24 hours, followed by a 12-hour incubation period. Subsequently, using a 8-row drum seeder, the seeds were sown in puddled soil at a line spacing of 20 cm. In case transplanted rice (M4), seedlings aged 26 days were uprooted and transplanted at a spacing of 20×15 cm using 2 seedlings per hill and ensuring a depth of about 3-4 cm. The seeding rate for this method was maintained at 45 kg/ha. The grains and straws were dried in sun to 14 percent and 20 percent moisture content, respectively and weighed separately as kg/plot. Then the yields of grain and straw were expressed in quintals per hectare. Hand weeding was done at critical weed growth period whenever necessary during the crop period.

**2.5: Statistical analysis:**

All the data pertaining to the present investigation wherever needed were statistically analyzed for split plot design as per the method described by Panse and Sukhatme (1985) known as Analysis of Variance (ANOVA). Critical differences (CD) at 5 per cent probability level was calculated only when the F value has been found to be significant.

CD = Sed (±) × √2 × × t value at 5% (2.447) for error (a) d.f.

3. results and discussion

**3.1 Growth and physiological parameters**

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| **Table 2: Effect of establishment methods and varieties on plant growth and physiological parameters of rice.** |
| **Treatments** | **Plant height (cm)** | **No. of tillers** | **Dry matter accumulation (g/m2)**  | **CGR (g/m2/day)** |
| M1V1 | 135.31b | 203.54bcd | 896.59def | 7.72fg |
| M1V2 | 120.34e | 174.84fg | 895.95def | 8.91de |
| M1V3 | 107.91i | 173.6fg | 867.3def | 9.32d |
| M1V4 | 87.72j | 154.62h | 833.79f | 7.7fg |
| M2V1 | 115.08f | 204.18bcd | 907.3def | 7.41g |
| M2V2 | 113.29fg | 188.17def | 894.9def | 7.33g |
| M2V3 | 112.78fgh | 180.3fg | 864.02ef | 7.47g |
| M2V4 | 110.59ghi | 169.45gh | 830.65f | 11.13c |
| M3V1 | 128.35c | 217.33ab | 1003.9bc | 6.24h |
| M3V2 | 114.87f | 199.98cde | 961.38bcd | 7.76fg |
| M3V3 | 112.08fgh | 181.11fg | 952.46bcde | 8.9de |
| M3V4 | 109.08hi | 174.26fg | 917.99cdef | 6.02h |
| M4V1 | 140.11a | 225.12a | 1174.58a | 8.46ef |
| M4V2 | 125.32cd | 212.5abc | 1039.38b | 8.81de |
| M4V3 | 123.64de | 207.53bc | 1024.04b | 12.64b |
| M4V4 | 110.23ghi | 186.42efg | 922.4cdef | 17.05a |

The method of establishment and varieties significantly influences the plant height of rice (Table 2). The plant height was significantly increased in variety Numali in transplanting method of establishment (M4V1) (140.11 cm), followed by variety Numali broadcast under puddled direct seeding method (M2V1) and the lowest value of plant height (87.72 cm) was recorded by BINA dhan 11 in dry broadcasting method of establishment (M1V4). Similarly, the maximum number of tillers/ m2 was observed in Numali variety in transplanting method of establishment (M4V1) (225.12/m2), followed by Numali variety sown with drum seeder in wet-DSR method of establishment (M3V1) (217.33/m2) and the lowest number of tillers/ m2 was recorded in BINA dhan 11 in dry broadcasting method of establishment (M1V4) (154.62/m2). among the different treatment combinations, the variety Numali in transplanting method of establishment (M4V1) recorded significantly the highest dry matter accumulation (595.49 g/m2) followed by variety Shraboni in transplanting method (M4V2) recording an average value of 540.01 g/m2 and the lowest dry matter accumulation was recorded by Dholi in puddled broadcast DSR (M2V3) method of establishment (383.47 g/m2). At harvest, the highest dry matter accumulation (1174.58 g/m2) was observed in variety Numali in transplanting method of establishment (M4V1), followed by variety Shraboni in transplanting method of establishment (M4V2) and the lowest values in respect of dry matter accumulation (830.65 g/m2) was recorded by BINA dhan 11 in Puddled broadcast DSR method of establishment (M2V4). BINA dhan 11 recorded the highest CGR (17.05 g/m2/day) under the TPR (M4V4) while the lowest CGR (6.02 g/m2/day) was recorded in Dholi under wet-DSR (M3V3) method of establishment. During the last phase of 90 days - harvest, Numali recorded the highest CGR (9.54 g/m2/day) under the TPR (M4V1) while the lowest CGR (4.13 g/m2/day) was recorded in Dholi under puddled broadcast DSR (M2V3) method of establishment. Similar result was also reported by Awan *et al.* (2007), Dileep *et al.* (2018), Ehsanullah *et al.* (2007), Chen *et al., (*2020).and Thapliyal *et al.* (2020).

**3.2 Weed parameters**

The method of establishment and variety significantly influences the weed dry matter accumulation.

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| **Figure 2: Weed dry matter at 30 DAS as influenced by methods of establishment and varieties.** |

At 30 DAS, significantly the lowest weed dry matter accumulation was found in the plot of BINA dhan 11 established by transplanting method (M4(V4) (15.05 g/m2) as compared to other treatment combinations, in contrast, highest weed dry matter accumulation was found in the plot of Dholi established by dry broadcasting method (M1V3).

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| **Figure 3: Weed dry matter at 60 DAS as influenced by methods of establishment and varieties.** |

At 60 DAS, variety Numali established by transplanting method (M4V1) recorded the lowest weed dry matter accumulation (10.23 g/m2) and the highest was recorded in the plot of BINA dhan 11 established by dry broadcasting (M1V4) (13.76 g/m2). Transplanting was more effective in reducing weed growth due to puddling, compared to other planting methods, which led to less weed mass in conventional transplanting, as the optimum spacing in transplanting prevented weeds from thriving. This resulted in lower weed density and less weed dry matter (Bhardwaj *et al.*, 2018a).

**3.1 Yield attributes and Yield**

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| **Table 3: Effect of establishment methods and varieties on yield attributes and yield of rice.** |
| **Treatment** | **No. of panicles/m2** | **No. of grains/ panicle** | **Grain Yield (t/ha)** | **Straw Yield****(t/ha)** | **Harvest Index (%)** |
| M1V1 | 174.75de | 123.03ghi | 3.04f | 4.81f | 38.76h |
| M1V2 | 172.17de | 116.46jk | 2.81g | 4.75fg | 37.15i |
| M1V3 | 155.79f | 111.42k | 2.57h | 4.51gh | 36.26j |
| M1V4 | 146.07f | 110.31k | 2.33h | 4.28hi | 35.3k |
| M2V1 | 189.47c | 138.7c | 3.75d | 5.54d | 40.34f |
| M2V2 | 180.16cde | 125.77fgh | 3.45e | 5.24e | 39.7g |
| M2V3 | 173.27de | 123.45ghi | 3.52e | 5.31de | 39.77g |
| M2V4 | 155.63f | 119.22ij | 2.4h | 4.19i | 36.4j |
| M3V1 | 202.75b | 135.85cd | 4.71ab | 6.03bc | 43.7a |
| M3V2 | 184.85cd | 131.23def | 4.58b | 5.9c | 43.33b |
| M3V3 | 177.2cde | 128.81efg | 4.07c | 5.39de | 43.01cd |
| M3V4 | 168.86e | 119.93hij | 3.31e | 4.63fg | 41.68e |
| M4V1 | 237.84a | 151.5a | 4.89a | 6.4a | 43.85a |
| M4V2 | 213.03b | 145.39b | 4.83a | 6.34a | 43.26bc |
| M4V3 | 183.47cd | 132.49de | 4.74ab | 6.25ab | 43.14bcd |
| M4V4 | 173.11de | 125.59fgh | 4.56b | 6.06bc | 42.9d |

The yield attributes and yield of different varieties of rice was significantly influences by the interaction effect of method of establishment and varieties (Table…). The maximum number of panicles/m2 (237.84/m2) was recorded by Numali established by TPR (M4V1) method over the other establishment methods and the minimum number of panicles/m2 (146.07/m2) was found in BINA dhan 11 established by dry broadcasting (M1V4) method. The maximum number of grains/panicle (151.50) was recorded by Numali established by TPR (M4V1) method over the other establishment methods and the least number of grains/panicle (110.31) was observed in BINA dhan 11 under dry broadcasting (M1V4) method. The interaction effect between method of establishment and variety in respect of grain yield was found to be significant. The maximum grain yield (4.89t/ha) was recorded by Numali established by TPR (M4V1) method over the other establishment methods and the lowest grain yield (2.33 t/ha) was found in variety BINA dhan 11 established by dry broadcasting (M1V4) method. In case of straw yield also, BINA dhan 11 under dry broadcasting (M1V4) method recorded significantly higher straw yield which was at par with Shraboni in transplanting method (M4V2). The harvest index was also recorded significantly higher for BINA dhan 11 under dry broadcasting (M1V4) method.

Interaction effect between methods of establishment and varieties showed significant effect on yield attributing parameters and yield in case of transplanting method of establishment (M4) over other methods i.e., wet-DSR (M3), puddled broadcast (M2) and dry Broadcast (M1) in Numali (V1) This might be due to the same reason of combined effect of spacing provided between the rows at specific distance and competition between the plants within the rows were minimum, deep penetration of roots which result in high efficiency of nutrient use. Which lead to vigorous growth of the plants in transplanting method resulting in higher yield attributing characters like numbers of panicle, panicle length, panicle weight etc. However wet-DSR (M3) was at par with the transplanting method in grain yield and harvest index. the least performance was exhibited by dry broadcasting method (M1). Similarly, variety Numali (V1) displayed superiority over the other varieties tested in the in terms of numbers of panicle/m2, yield attributing character and yield parameters like grain yield, straw yield and harvest index, where the lowest data was observed in variety BINA dhan-11. However, variety Shraboni (V2) showed at par result with the other two varieties in yield parameters.

Interaction effect between methods of establishment and varieties showed significant effect on yield attributing parameters and yield in case of transplanting method of establishment (M4) over other methods i.e., wet-DSR (M3), puddled broadcast (M2) and dry Broadcast (M1) in Numali (V1) This might be due to the same reason of combined effect of spacing provided between the rows at specific distance and competition between the plants within the rows were minimum, deep penetration of roots which result in high efficiency of nutrient use. Which lead to vigorous growth of the plants in transplanting method resulting in higher yield attributing characters like numbers of panicle, panicle length, panicle weight etc. However wet-DSR (M3) was at par with the transplanting method in grain yield and harvest index. the least performance was exhibited by dry broadcasting method (M1).

 Similarly, variety Numali (V1) displayed superiority over the other varieties tested in the in terms of numbers of panicle/m2, yield attributing character and yield parameters like grain yield, straw yield and harvest index, where the lowest data was observed in variety BINA dhan-11. However, variety Shraboni (V2) showed at par result with the other two varieties in yield parameters. Similar result was obtained by Maniraj *et al*. (2021).

**3.1 Nutrient status**

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| **Table 4: Effect of establishment methods and varieties on Nitrogen uptake by grain straw of rice and available in soil.** |
| **Treat Name** | **N Uptake of Grains (kg/ha)** | **N uptake of straw (kg/ha)** | **Available N (kg/ha)** |
| M1V1 | 33.88fg | 26.52c | 220.84b |
| M1V2 | 30.11fgh | 23.38cde | 221.02b |
| M1V3 | 26.26ghi | 21.03cde | 221.13b |
| M1V4 | 17.84i | 13.44e | 242.26a |
| M2V1 | 46.39cde | 44.13ab | 219.81bc |
| M2V2 | 37.85ef | 25.27cd | 214.46e |
| M2V3 | 36.03f | 24.46cde | 221.46b |
| M2V4 | 22.62hi | 15.12de | 222.6b |
| M3V1 | 70.89ab | 36.74b | 215.87e |
| M3V2 | 63.71b | 40.56ab | 213.75ef |
| M3V3 | 54.97c | 23.68cde | 222.51b |
| M3V4 | 32.69fg | 19.38cde | 219.35bcd |
| M4V1 | 78.73a | 48.44a | 210.32f |
| M4V2 | 53.01cd | 37.58b | 216.39de |
| M4V3 | 64.92b | 37.43b | 216.7cde |
| M4V4 | 45.49de | 36.11b | 221.18b |

Interaction effect between methods of establishment and varieties significantly influences the nitrogen uptake by grain, straw and available nitrogen in soil. The N uptake by grain of variety Numali under both transplanting (M4V1) and drum seeded wet-DSR (M3V1) were statistically at par, the value being 78.73 and 70.89 kg/ha. For straw also, the variety Numali showed maximum N uptake by straw (48.44 kg/ha) under transplanting method (M4V1) which was significantly superior over all other treatment combination. Variety BINA dhan 11 showed the least N uptake by straw when sown by dry broadcast method (M1V4). This might be due to the combined effect of spacing provided between the plant at specific distance and competition between the plants were minimum, deep penetration of roots which result in high efficiency of nutrient use. Which lead to vigorous growth of the plants in transplanting method resulting in higher N content and uptake of N. However wet-DSR (M3) was at par with the transplanting method in grain yield and harvest index. the least performance was exhibited by dry broadcasting method (M1). Similarly in variety Numali (V1) displayed superior N content, uptake and total uptake over other varieties tested in the experiment where the lowest data was observed in variety BINA dhan-11. However, in case of variety Shraboni (V2) it shows at par with all other two varieties in yield parameters except Numali (V1). This might be due to the combined effect of spacing provided between the plant at specific distance and competition between the plants were minimum, deep penetration of roots which result in high efficiency of nutrient use. Which lead to vigorous growth of the plants in transplanting method resulting in higher N content and uptake of N. However wet-DSR (M3) was at par with the transplanting method in grain yield and harvest index. the least performance was exhibited by dry broadcasting method (M1). Similar finding was reported by Gangwar *et al.,* (2008).

**3.2 Economics:**

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| **Table 5: Energetics on rice harvest as influence by method of establishment and varieties of rice.** |
| **Treatments** | **Cost of cultivation** **(Rs/ ha)** | **Gross return** **(Rs/ ha)** | **Net return (Rs/ha)** | **B:C** |
| M1V1 | 30897.83 | 62594.60 | 31696.77 | 1.03 |
| M1V2 | 30897.83 | 57882.32 | 26984.49 | 0.87 |
| M1V3 | 30897.83 | 52851.69 | 21953.87 | 0.71 |
| M1V4 | 30897.83 | 48085.94 | 17188.11 | 0.56 |
| M2V1 | 31520.75 | 77182.86 | 45662.11 | 1.45 |
| M2V2 | 31520.75 | 71100.10 | 39579.35 | 1.26 |
| M2V3 | 31520.75 | 72509.04 | 40988.29 | 1.30 |
| M2V4 | 31520.75 | 49412.09 | 17891.34 | 0.57 |
| M3V1 | 30576.23 | 97014.56 | 66438.33 | 2.17 |
| M3V2 | 30576.23 | 94401.05 | 63824.82 | 2.09 |
| M3V3 | 30576.23 | 83847.38 | 53271.15 | 1.74 |
| M3V4 | 30576.23 | 68244.34 | 37668.11 | 1.23 |
| M4V1 | 41431.51 | 100734 | 59302.48 | 1.43 |
| M4V2 | 41431.51 | 99566.66 | 58135.15 | 1.40 |
| M4V3 | 41431.51 | 97686.93 | 56255.42 | 1.36 |
| M4V4 | 41431.51 | 93882.73 | 52451.22 | 1.27 |

A perusal of the data on economics status revealed that the cost of cultivation of rice was incurred with a value of Rs.41431.51/ha in transplanting methods The highest gross return of Rs.100734/ha was achieved under the treatment combination of variety Numali raised in transplanting method (M4V1) followed closely by Rs. 99567/ha in variety Shraboni grown in transplanting method (M4V2) which fetched a gross return of Rs. 99567/ha. However, Higher net return of Rs.66438/ha was obtained by growing variety Numali sown by drum seeded wet-DSR method (M3V1) then it can be concluded that drum seeding of sprouted seeds by wet-DSR method followed in variety Numali and Shraboni were more profitable. (M4V2). The highest B-C ratio (2.17) was obtained by growing variety Numali in Wet-DSR method (M3V1) followed by the treatment combination of variety Shraboni grown with the same treatment (M3V2).

**3.3 Energetics:**

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| **Table 6: Energetics on rice harvest as influence by method of establishment and varieties of rice.**85 |
| **Treatments** | **Energy input (MJ/Unit)** × **103** | **Energy output (MJ/Unit)** × **103** | **Net energy return (MJ/Unit)** × **103** | **Energy use efficiency (%)** |
| M1V1 | 11.11 | 102.92 | 91.82 | 9.27 |
| M1V2 | 11.11 | 101.60 | 90.49 | 9.15 |
| M1V3 | 11.11 | 95.66 | 84.55 | 8.61 |
| M1V4 | 11.11 | 89.48 | 78.37 | 8.06 |
| M2V1 | 10.78 | 118.33 | 107.55 | 10.97 |
| M2V2 | 10.78 | 115.79 | 105.01 | 10.74 |
| M2V3 | 10.78 | 113.44 | 102.66 | 10.52 |
| M2V4 | 10.78 | 96.67 | 85.89 | 8.97 |
| M3V1 | 9.80 | 137.08 | 127.27 | 13.9 |
| M3V2 | 9.80 | 136.27 | 126.46 | 13.90 |
| M3V3 | 9.80 | 125.81 | 116.01 | 12.83 |
| M3V4 | 9.80 | 119.30 | 109.49 | 12.17 |
| M4V1 | 10.01 | 152.46 | 142.44 | 15.22 |
| M4V2 | 10.01 | 149.90 | 139.88 | 14.97 |
| M4V3 | 10.01 | 145.51 | 135.50 | 14.53 |
| M4V4 | 10.01 | 143.61 | 133.59 | 14.34 |

The maximum amount of energy input (11.11 × 103 MJ/unit) was spent for the establishment method of dry broadcast seeding in unpuddled soil bueshened in to line sown crop by self-propelled paddy weeder for all the varieties. The higher energy output (152.46 × 103 MJ/unit) was obtained from the treatment combination of sowing variety Numali by transplanting method (M V1). The same treatment combination i.e., M4V1 could also achieve the maximum net energy return. (142.44 × 103 MJ/unit) followed closely by all the other three varieties (Shraboni, Dholi and BINA dhan11) raised in transplanting method. In terms of energy use efficiency, the treatment combination of raising variety Numali by transplanting method was found to be the more efficient (M4V1) recording an efficiency of 15.22 % followed closely by the other three varieties under the transplanting method. The drum seeding in wet-DSR method (M3) recorded an energy efficiency in the range of 12.17 to 13.90 %.

4. Conclusion

From this study, it was revealed that drum seeding of sprouted seeds in puddled soil (wet-DSR) can be an effective agronomic technique for establishing rice crop for the 102 medium-lowland rice ecosystems of assam. This proved to be a faster and easier method of rice establishment, requiring less resources like water, seed and labour in comparison to the conventional puddled transplanting, evident from producing statistically at par yield and being the most energy efficient method. From economic standpoint too, drum seeded wet-DSR method was found to be the most profitable option of rice establishment. Adoption of medium duration varieties like Numali or Shraboni is a suitable option for enhancing cropping intensity of assam for the rice based double cropped areas, as evident from its early maturity. However, the results are based on only one year of experimentation, therefore, further investigations are needed for arriving at a concrete recommendation.

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