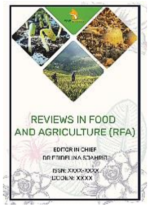
ZIBELINE INTERNATIONAL™ PUBLISHING

ISSN: 2735-0312 (Online)
CODEN: RFAEAW

Reviews In Food And Agriculture (RFNA)

DOI: http://doi.org/10.26480/rfna.01.2023.07.12



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RESEARCH ARTICLE

RESPONSE OF DIFFERENT SEEDLING ESTABLISHMENT METHODS ON GROWTH AND YIELD OF RICE IN TERAI REGION OF NEPAL

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ARTICLE DETAILS

Article History:

Received 22 December 2022
Revised 01 January 2023
Accepted 08 February 2023
Available online 10 February 2023

ABSTRACT

The experiment was conducted at Agronomy farm, Rampur Campus, Chitwan to evaluate the effect of seedlings establishment methods on growth and yield of main season rice, 2021. RCBD design was used with four replications and six treatments viz. T1- Farmers' practice (random transplanting), T2- traditional transplanting (20cm*20cm), T3- System of Rice Intensification, T4- non-puddled transplanting, T5- wet DSR (broadcasting), and T6- wet DSR (line-sowing). The foundation seed of Ramdhan was used as a study material. Data were recorded on different growth, yield and yield attributing traits. ANOVA revealed statistically significant differences ($p<0.05$) for all parameters except number of effective tillers m^{-2}, number of unfilled grains panicle^{-1} and sterility percentage. Lowest effective tillers m^{-2}, biological yield, number of filled and total grains panicle^{-1} was observed in T6 resulting in lower grain yield (4.92 tonha^{-1}). Highest thousand grains weight (23.18gm), grain yield (6.13 tonha^{-1}), and harvest index (22.13%) were recorded in T3. The highest grain yield of T3 was followed by T2 (5.82tonha^{-1}) at par with T1 (5.73tonha^{-1}). The minimum sterility percentage was 30.49% in T4. Plant height at 120 DAS, number of tillers hill^{-1} 120 DAS, number of leaves hill^{-1} 105DAS, LAI 105DAS, panicle length and no. of filled grains panicle^{-1} expressed a positive correlation with grain yield. The regression value showed that the maximum variation in grain yield was governed by PH at 120DAS (62.37%), LAI at 105 DAS (61.85%), and panicle length (47.04%) primarily.

KEYWORDS

Broadcasting, Direct Seeded, Growth, Transplanting, Yield

1. INTRODUCTION

Rice (*Oryza sativa* L.) is the most important and widely cultivated staple crop of the world. It provides about 21 % of the total calorie intake of the world population (Parameswari et al., 2014). Global production of cereals in the year 2019 is 2.97 billion tonnes out of which production of paddy account for 755.47 million tonnes (25.36%)(FAOSTAT, 2021). Asia is the leading continent in the production of paddy (677.27 million tonnes) followed by Africa (38.77 million tonnes). China is the major producer of paddy in the world that contributes 27.98% of global paddy production followed by India (23.51%) and Indonesia (7.23%) which is at par with Bangladesh. Nepal contributes 0.74% (5.61 million tonnes) to global paddy production (FAOSTAT, 2021). Paddy ranks first in terms of area cultivated (1,473,474hectares) production (5,621,710 metric tons), and productivity (3.82mtha^{-1}) in Nepal (MoALD, 2021). Paddy comprises 50.56% of total cereals production in Nepal. Madhesh Pradesh is the top producer of paddy in Nepal followed by province no. 1 and Lumbini Pradesh whereas; Bagmati pradesh ranks fifth out of seven provinces of Nepal i.e. 9.06% of total paddy production of Nepal. Chitwan district contributes 22.45% and 0.51% of Bagmati pradesh and national paddy production respectively. In Chitwan, the total area under cereal crop cultivation is 62,281 hectare and the production is 237,894 metric tons with the yield 3.82 mtha^{-1} and the area cultivated with paddy is 28,457ha with a total production of 113,376 metric tons and productivity of 3.98mt ha^{-1} (MoALD, 2021).The contribution of the agricultural sector (agriculture, forest, and fisheries) to the total Gross Domestic Product is estimated to be 25.8% and its contribution to the economic growth is estimated to be 20.2% in the fiscal year 2020/21(MoF, 2021).

Based on land preparation and crop establishment techniques, rice can be grown by several methods such as Direct Seeding (DSR), Transplanting (TPR), and System of Rice Intensification (SRI). In DSR technology, instead of transplanting seedlings from the nursery, seeds are sown directly in the field. Pre- germinated seeds can be sown into puddled soil (wet seeding) or standing water (water seeding) or prepared seedbed (dry seeding) (Kumar et al., 2018). DSR method is a promising alternative for rice establishment in the area with scarce labor and water (Lama and Marahatta, 2018). In addition, it shortens the cropping duration by a few weeks, but more work needs to be put into implementing suitable management strategies and breeding programs (Poudel, 2020). Climate change, lack of sufficient farm labors and irrigation facilities, and deteriorating soil health can be vulnerable to rice production in Nepal. Manual transplanting of the seedlings into puddled soil is the major practice of Asian farmers (Kumar et al., 2018). It is usually done under favorable rainfed and irrigated lowland in Tropical Asia (Sangeetha and Baskar, 2015). In wetlands, seedlings are transplanted into prepared land after irrigation (Lama and Marahatta, 2018). Crop growth and yield performance are affected by puddling as it deteriorates the soil texture and creates compaction of soil particles. SRI (System of Rice Intensification) technique is a more economic and eco-friendly rice establishment method that adopts the principle of transplanting young single seedling at wider spacing and alternate wetting and drying irrigation pattern. More organic matter and lesser chemical fertilizers are used in this method. 75% seed cost and 30-40% water is saved in this method (Rajiv and Dabbas, 2012; Majumder et al., 2019). Successful establishment of young seedlings is difficult in the monsoon rain based

Quick Response Code	Access this article online	
	Website: www.rfna.com.my	**DOI:** 10.26480/rfna.01.2023.07.12

Cite The Article: Khushubu Rai, Oshna Kulung, Mamta Rana, Anita Tamang, Achyut Gaire (2023). Response of Different Seedling Establishment Methods on Growth and Yield of Rice in Terai Region of Nepal. *Reviews In Food And Agriculture, 4(1): 07-12.*

conditions. To achieve the required number of plants per unit area, periodic gap filling is required. SRI spread is therefore of minimal magnitude (Sangeetha and Baskar, 2015). Generally traditional practices of rice cultivation are followed that result in lower productivity and profitability of rice. Transplanting is a resource and cost intensive method as nursery bed preparation, seedling raising, and transplanting are labor intensive and time consuming processes (Nahar et al., 2018). This research will help farmers choose appropriate and efficient rice planting methods to increase yields. Therefore, a study was conducted in Kairahani, Chitwan, Nepal to evaluate different rice cultivation methods in terms of different growth, yield and yield-attributing traits.

2. Materials and Methods

2.1 Description of the Experimental Site

The experiment was conducted in the agronomy farm of the Institute of Agriculture and Animal Science (IAAS), Rampur Campus, Khairahani, Chitwan which lies between 27.608263°N and 84.562570°E at the elevation of 190 masl.

2.2 The Climatic Condition of the Experimental Site

The climatic condition of the research site during the research period is shown in Figure 1 below.

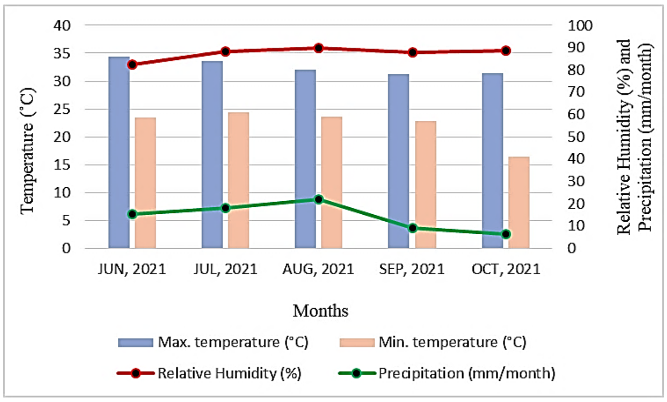


Figure 1: Climatic data of the experimental site during the research period (Source: NASA POWER)

2.3 Experimental Materials Description

Variety- Ramdhan (Foundation seed)

Date of experiment- 6th June 2021 to 17th Oct 2021

Table 1: Treatment Details

Treatment number	Treatment name
T1	Farmers' practice (Random transplanting)
T2	Traditional transplanting (20cm*20cm)
T3	SRI (25cm*25cm)
T4	Non-puddled transplanting (20cm*20cm)
T5	Wet DSR (broadcasting)
T6	Wet DSR (line sowing: 20cm*5cm)

2.4 Experimental Design and Crop Management

The experiment was conducted in a Randomized Complete Block Design (RCBD) with six treatments and four replications. The size of each experimental plot was $9m^2$(3m × 3m) with inter-replication and inter- plot spacing of 1m each. The gross field size was $345m^2$. The rice variety used for the experiment was Ramdhan. The seed was subjected to salt-water treatment followed by Bavistin treatment @2gm/kg. For transplanting, seedlings were raised on raised dry seed beds. Bavistin treated pre-germinated seeds were sown in wet direct seeding of rice. The crop geometry differs as per the treatment nature (Table 1). The Farm Yard Manure was applied at the rate of 6 tons per hectare for T1, T2, T4, T5, and T6 whereas 10 tons per hectare for T3. Similarly, the applied dose of chemical fertilizer varied as; 100:30:30 kg $NPKha^{-1}$for T1, T2, and T4, 50:30:20 kg $NPKha^{-1}$for T3 and 100:40:30 kg $NPKha^{-1}$for T5 and T6. The half dose of N and the full dose of P and K were applied before the sowing. The remaining half dose of N was top-dressed at tillering and panicle initiation stage in equal split. Zinc sulphate was applied for zinc supplement. The seed rate used for SRI, DSR was 8 $kgha^{-1}$ while 45 $kgha^{-1}$ for transplanting. The experimental field was ploughed with a cultivator initially and leveled and puddled manually. Weeds and stubbles were removed manually. Pre-emergence application of Pretilachlor 50% EC @ 2.5ml/lit of water was sprayed in all the field within 3-4 days after transplanting and direct seed sowing and later on weeds were managed manually. The thinning and gap filling of DSR was done at 11 days after sowing. In case of SRI and Transplanting, 15 days and 24 days old seedlings were transplanted respectively with gap filling after seven days. For water management, alternate wetting and drying (AWD) was done every three days in SRI whereas other treatments were irrigated by flooding as per the requirements of crop.

2.5 Data Collection

Data were recorded from five randomly selected hills per plot for different qualitative and quantitative traits like plant height, LAI, number of tillers $hill^{-1}$, days to 50% tillering, weed count, fresh and dry weight of weeds, panicle length, number of grains $panicle^{-1}$, number of filled grains $panicle^{-1}$, number of unfilled grains $panicle^{-1}$, sterility %, number of effective tillers m^{-2}, number of ineffective tillers m^{-2}, biological yield, grain yield, straw yield, harvest index, and thousand grain weight.

2.6 Statistical Analysis

The data collected were entered in Microsoft Excel 2013 and analyzed using R Studio (Version 1.4.1717).

3. Results and Discussion

Plant height was significantly influenced by the seedling establishment method. Statistically, a significant difference ($p<0.05$) was observed for plant height at 90DAS and 120DAS, whereas plant height was not significantly different at 60DAS. The mean plant heights at 60DAS, 90DAS and 120DAS are 81.849cm, 102.158cm and 123.872cm respectively. At 60DAS traditional transplanting had the tallest plants (85.31cm) followed by wet DSR broadcasting (82.48cm). Shortest plants were observed in non-puddled transplanting (79.43cm). Likewise, at 90DAS tallest plants were observed for farmers' practice (105.325cm) followed by SRI (104.415cm) whereas wet DSR broadcasting had the shortest plants (96.4). Furthermore, at 120DAS SRI had the tallest plants (130.25cm). Similar result for SRI was recorded by other scientist as well (Tomar et al., 2018; Duttarganvi et al., 2016; Rahman et al., 2019). The reason behind this might be wider spacing, sufficient sunlight and nutrients available in SRI than in other close spaced plants (Tomar et al., 2018). In addition, AWD also supports higher plant height due to good aeration and better root growth (Duttarganvi et al., 2016). On the other hand, the shortest plants were noted in wet DSR broadcasting (113.45cm), 10.42 cm shorter than the mean height. As the plant ages the height and dry matter production of crops increases (Bhaskar et al., 2019).

Table 2: Plant Height of Rice at Different Days after Sowing (DAS) in Chitwan During the Rainy Season Of 2021

Treatments	60DAS	90DAS	120DAS
Farmers' practice (Random transplanting)	81.45	105.325	129.28
Traditional transplanting (20cm*20cm)	85.31	104.405	127.14
SRI	81.765	104.415	130.25
Non-puddled transplanting	79.43	103.745	126.5
Wet DSR (broadcasting)	82.48	96.4	113.45
Wet DSR (line sowing)	80.66	98.655	116.61
Grand mean	81.849	102.158	123.872
F-test	NS	*	***
CV	5.767	4.781	3.127
LSD,0.05	7.012	7.256	5.755

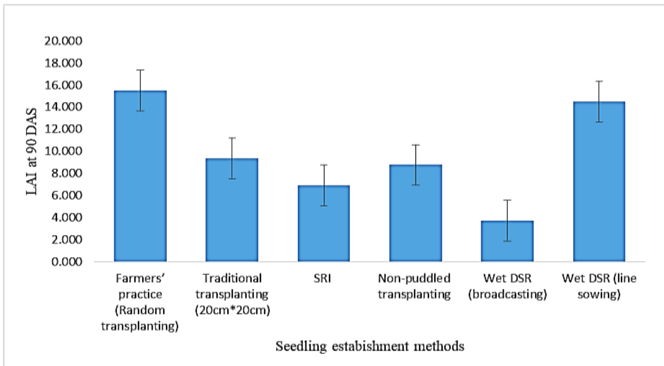


Figure 2: Bar diagram showing Leaf Area Index (LAI) as influenced by different seedling establishment methods

Cite The Article: Khushubu Rai, Oshna Kulung, Mamta Rana, Anita Tamang, Achyut Gaire (2023). Response of Different Seedling Establishment Methods on Growth and Yield of Rice in Terai Region of Nepal. *Reviews In Food And Agriculture, 4(1): 07-12.*

Statistically, treatments were significantly different for the LAI at 90 DAS at 0.1% significance level. Highest LAI was observed in Farmer's practice random transplanting (15.50), whereas lowest LAI was observed in wet DSR broadcasting (3.733). The Farmers' practice of random transplanting was significantly different from all methods except wet DSR line sowing and vice-versa. Similarly, wet DSR broadcasting is significantly different from all practices except SRI as shown by the error bars in Figure 2.

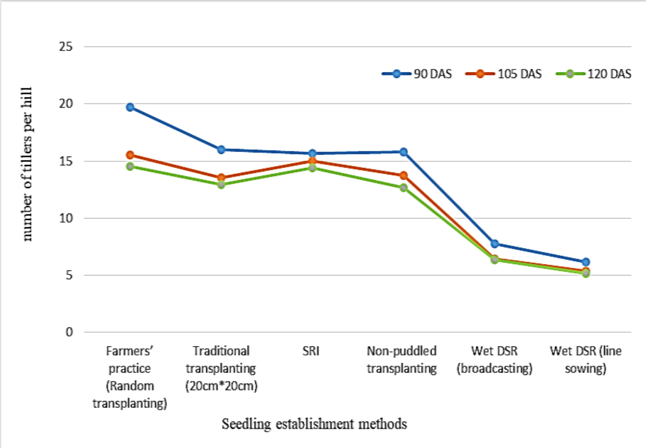


Figure 3: Graph showing number of tillers hill^{-1} as influenced by different seedling establishment methods

Crop establishment techniques differed significantly for the number of tillers hill^{-1} at different DAS. Maximum numbers of tillers were observed in farmers' practice random transplanting in all days of data collection. The number of tillers hill^{-1} in farmers' practice random transplanting was 20, 16, and 15 at 90DAS, 105DAS, and 120DAS respectively. The minimum number of tillers were observed in wet DSR line sowing at 90DAS (6) and 105DAS (5); however, wet DSR broadcasting showed the lowest number of tillers hill^{-1} at 120DAS (6). Higher tillers hill^{-1} in conventional transplanting (random and traditional transplanting) and lower in direct seeding was observed (Rahman et al., 2019). The SRI holds a lesser number of tillers hill^{-1} in early days of crop establishment. This might be due to use of single seedling, slow release of nutrients from organic manure, and low dose of Nitrogen.

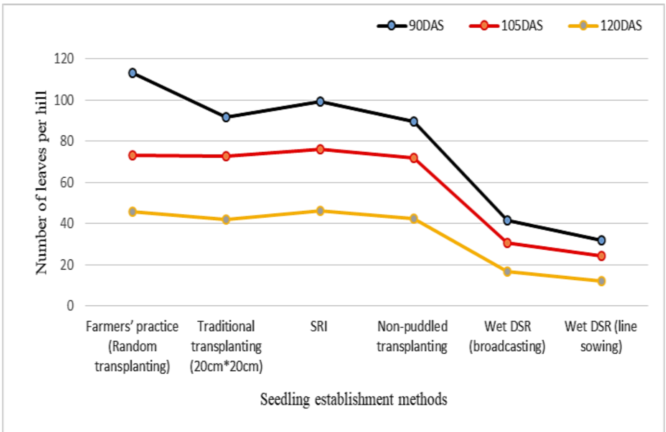


Figure 4: Graph showing Number of leaves hill^{-1} as influenced by different seedling establishment methods

Highly significant differences (P<0.01) were observed for the number of leaves hill^{-1} at 90DAS, 105DAS, and 120DAS. Maximum number of leaves hill^{-1} was observed in farmers' practice random transplanting at 90 DAS and 105DAS whose value was 113 and 73 respectively (Figure 4). But, SRI showed the maximum number of tillers hill^{-1} at 105DAS (46). Similarly, the lowest number of leaves hill^{-1} was recorded in wet DSR line sowing at 90DAS and 120DAS and their average value was 32 and 12 respectively. However, wet DSR broadcasting showed maximum average value at 105DAS i.e. 31.

Statistically, a highly significant difference among the treatments was observed for number of effective tillers m^{-2}, panicle length and number of grains panicle^{-1} whereas significant difference was revealed for number of filled grains panicle^{-1}, from the result as shown in Table 3. Non-significant differences were observed for the number of non-effective tillers m-2, number of unfilled grains panicle-1, and sterility percentage. A group researchers reported similar results for these traits (Rahman et al., 2019).

Table 3: Yield contributing traits of rice evaluated in Chitwan during the rainy season of 2021

Treatments	noETpMs	noNETpMs	PL (cm)	noFGpP	noUFGpP	Grains panicle^{-1}	Sterility%
Farmers' practice (Random transplanting)	472	35	27.950	120	58	178	32.41
Traditional transplanting (20cm*20cm)	300	31	28.126	106	52	158	32.81
SRI	242	10	27.923	107	48	156	31.03
Non-puddled transplanting	304	19	27.705	114	50	164	30.49
Wet DSR (broadcasting)	154	1	25.808	79	45	123	36.35
Wet DSR (line sowing)	635	15	25.861	87	44	131	34.30
Grand mean	**351**	**18**	**27.229**	**102**	**49**	**152**	**32.897**
F-test	***	**NS**	**	*	**NS**	**	**NS**
CV	**19.880**	**110.658**	**2.835**	**14.551**	**16.641**	**11.560**	**14.852**
LSD,0.05	**103.688**	**30.370**	**1.147**	**22.100**	**12.215**	**26.043**	**7.258**

Note: *Significant at 5% level of significance, ** significant at 1% level of significance, *** significant at 0.1% level of significance, NS= Non-significant. CV= Coefficient of Variance and LSD= Least Significant Difference, noETpMs= number of Effective Tillers m-2, noNETpMs= number of Non-Effective Tillers m-2, PL= panicle length, noFGpP= number of Filled Grain per Panicle, noUFGpP= number of unfilled grain per panicle.

Highest number of effective tillers m^{-2} was observed in wet DSR line sowing (635) followed by farmer's practice random transplanting (472) and the lowest number of effective tillers m^{-2} was obtained in wet DSR broadcasting (154). A group researchers reported similar result for wet DSR line sowing (Poudel et al., 2020). This might be due to close crop geometry resulting in more plant population in DSR line sowing. The number of effective tillers m^{-2} was lesser in SRI than conventional methods (random and traditional transplanting) which might be due to lesser tiller number per meter square (Rajiv and Dabbas, 2012). Farmers' practice random transplanting (35) had the highest number of non-effective tillers m^{-2} followed by traditional transplanting (31) however the lowest number of non-effective tillers m^{-2} was observed in wet DSR broadcasting (1). Longest panicle was observed in traditional transplanting (28.126cm) followed by farmers' practice random transplanting (27.950cm) while the shortest panicle was found in wet DSR broadcasting (25.808 cm) which is at par to wet DSR line sowing (25.861 cm). Similar result was reported by other researchers as well (Dendup and Chhogyel, 2018; Rahman et al., 2019; Bhardwaj et al., 2018). The panicle was longer in conventional methods (random and traditional methods) than in SRI (Rajiv and Dabbas, 2012). Short panicle in DSR might be due to higher number of effective tillers m^{-2}, higher competition with weeds, and also among the tillers for photosynthesis in comparison to the traditional transplanting which reduced the panicle length (Ghasal et al., 2014).

Farmer's practice random transplanting (120) had a maximum number of filled grains panicle^{-1} which was followed by non- puddled transplanting (114) whereas wet DSR broadcasting (79) had the lowest number of filled grains panicle^{-1}. Number of filled grains panicle^{-1} was higher in conventional transplanting than wet DSR broadcasting (Bhardwaj et al., 2018). The highest number of unfilled grains panicle^{-1} was observed in farmer's practice random transplanting (58) followed by traditional transplanting (52) but the least number of unfilled grains panicle^{-1} was observed in wet DSR line sowing (44). Even though several yield attributing traits of conventional methods were better than SRI, the fact that non-effective tillers and unfilled grains were higher in them might have affected the grain yield resulting lower yield than SRI.

The highest number of grains panicle^{-1} was observed in farmer's practice random transplanting (178) followed by non-puddled transplanting (164) and the lowest number of grains panicle^{-1} was observed in wet DSR broadcasting (123). Conventional transplanting had higher grains panicle-1 than direct seeded one (Rahman et al., 2019; Bhardwaj et al., 2018). The highest sterility % was observed in wet DSR broadcasting (36.35) followed by wet DSR line sowing (34.30) and the lowest sterility % was observed in non-puddled transplanting (30.49). A group researchers reported high sterility % in DSR (Poudel et al., 2020).

Statistically, a highly significant difference among treatments was observed for biological yield and straw yield (Table 4). Harvest index, thousand grain weight, and grain yield were also influenced significantly by various seedling establishment methods. Highest biological yield was obtained in traditional transplanting (34.65 tonha^{-1}) followed by non-puddled transplanting (34.42 tonha^{-1}). Lowest biological yield was obtained in Wet DSR broadcasting (25.88 tonha^{-1}). Wet DSR line sowing gave maximum straw yield which was at par with SRI and non-puddled transplanting. This might have resulted due to higher plant population as the spacing was less. Nevertheless, lowest straw yield was obtained in traditional transplanting i.e. 7.65 tonha^{-1}.

The significantly highest harvest index was recorded under treatment SRI (22.13%) followed by Wet DSR line sowing (20.74%). The lowest harvest index was recorded in non-puddled transplanting (17.60%). Highest harvest index was reported in SRI (Tomar et al., 2018).

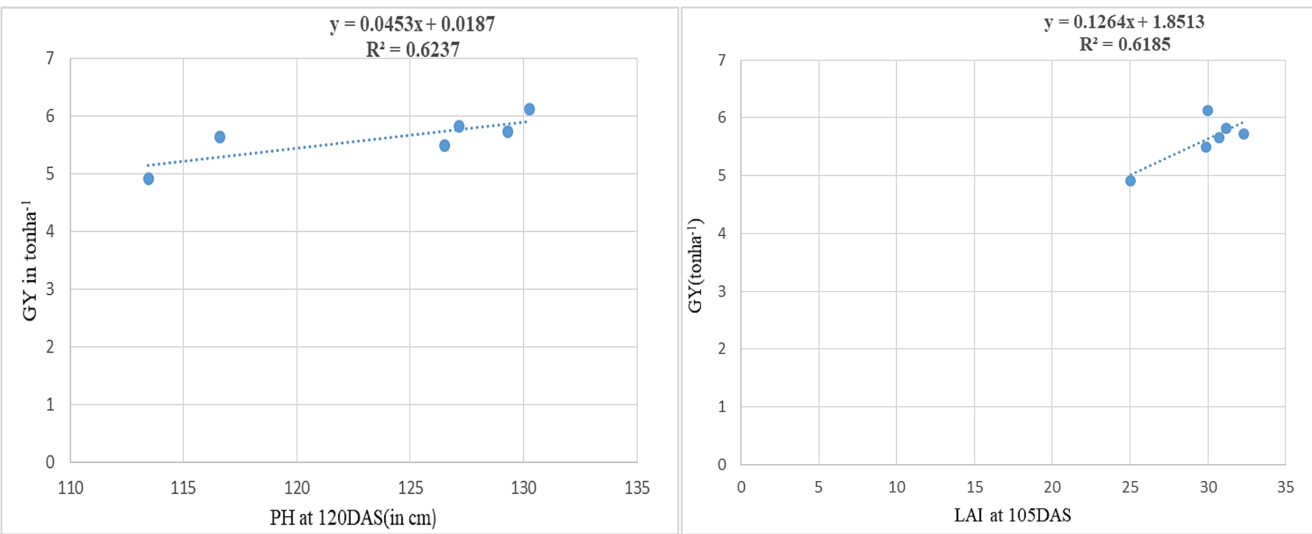
Table 4: Yield and Yield Contributing Traits of Rice Evaluated in Chitwan during the Rainy Season of 2021

Treatments	BY (tonha^{-1})	SY (tonha^{-1})	HI (%)	Final TGW (g)	GY (tonha^{-1})
Farmers' practice (Random transplanting)	34.27	7.75	18.52	21.19	5.73
Traditional transplanting (20cm*20cm)	34.65	7.65	18.93	20.92	5.82
SRI	28.04	10.22	22.13	23.18	6.13
Non-puddled transplanting	34.42	10.06	17.60	21.15	5.50
Wet DSR (broadcasting)	25.88	9.35	19.74	22.87	4.92
Wet DSR (line sowing)	28.23	10.53	20.74	22.25	5.65
Grand mean	30.915	9.258	19.611	21.929	5.625
F-test	***	**	*	*	*
CV	6.677	11.054	9.955	4.665	8.697
LSD,0.05	3.067	1.52	2.900	1.520	0.727

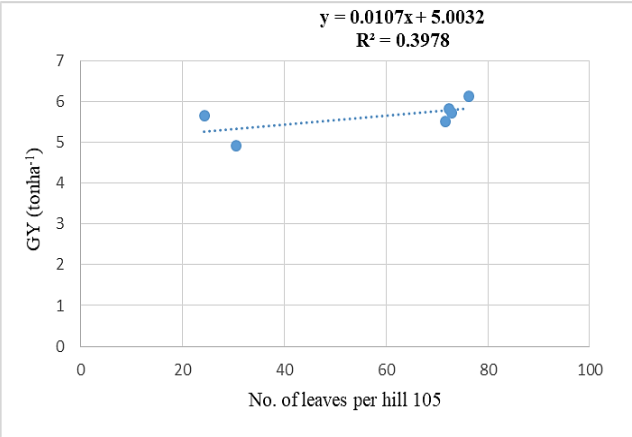
Note: *Significant at 5% level of significance, ** significant at 1% level of significance, and *** significant at 0.1% level of significance. CV= Coefficient of Variance & LSD= Least Significant Difference, BY= Biological Yield, SY= Straw Yield, GY= Grain Yield, HI= Harvest Index, TGW= Thousand grain weight

The highest thousand grain weight was noticed under treatment SRI (23.18g) followed by Wet DSR broadcasting (22.87g). Other researchers found similar result for SRI (Dendup & Chhogyel, 2018; Talla & Jena, 2014; Hugar et al., 2009; Bhandari et al., 2020). The lowest thousand grain weight was recorded in traditional transplanting (20.92g). Wider spacing of plants in SRI reduces the competition for nutrients which result in better nutrient supply that ultimately forms bold grains (Rajiv and Dabbas, 2012).

Highest grain yield was observed in SRI (6.13 tonha^{-1}) followed by traditional transplanting (5.82 tonha^{-1}). Other researchers also reported highest grain yield for SRI (Duttarganvi et al., 2016; Tomar et al., 2018; Bhandari et al., 2020; Chen et al., 2013; Khadka et al., 2014). Lowest grain yield was observed in Wet DSR broadcasting (4.92tonha-1). A group researcher also supported this result (Tomar et al., 2018). AWD practice might have supported increased yield of SRI as it provides good aeration and better root growth aiding sufficient nutrients for vegetative and reproductive growth (Duttarganvi et al., 2016). Though several yield attributing traits like panicle length, number of filled grains panicle^{-1}, grains panicle^{-1}, number of effective tillers m^{-2} was better in conventional transplanting, SRI showed significantly higher grain yield. This might be due to proper grain filling in SRI comparatively. Uncertain heavy rainfall during harvest as a result of climate change caused poor grain filling and shattering loss in conventional transplanting.



(a) **(b)**



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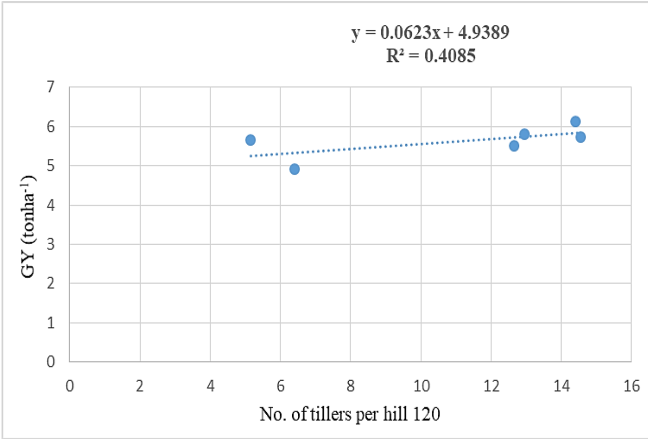

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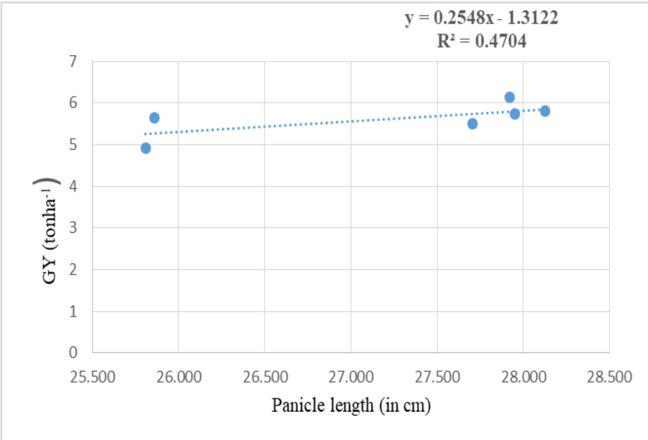

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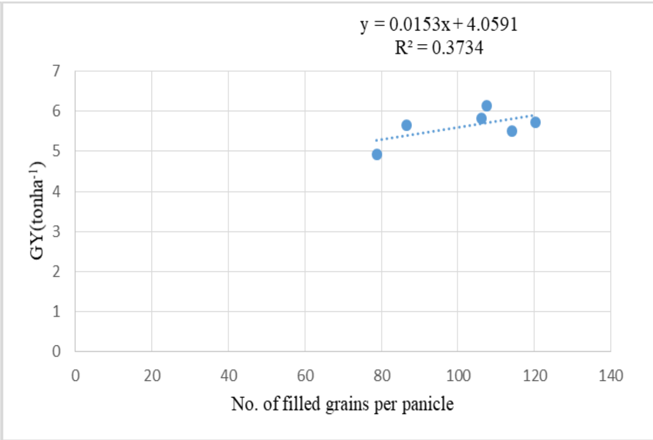

(f)

Figure 5: Regression analysis of Grain yield (tonha^{-1}) as affected by different traits

The equations in the Figure 5 revealed that a unit change in independent variables (PH at 120DAS, LAI at 105 DAS, no. of leaves hill^{-1} at 105DAS, no. of tillers hill^{-1}at 120DAS, panicle length and no. of filled grains panicle^{-1}) resulted change in grain yield by 0.045, 0.13, 0.01, 0.06, 0.25 and 0.02 units respectively. This shows positive correlation of those traits with the grain yield. Similarly, the value of R^2 indicated that 62.37%, 61.85%, 39.78%, 40.85%, 47.04% and 37.34% of the variation in grain yield was explained by PH at 120DAS, LAI at 105 DAS, no. of leaves hill^{-1} at 105DAS, no. of tillers hill^{-1}at 120DAS, panicle length and no. of filled grains panicle^{-1}respectively. Very tall plants may cause lodging, however sufficient plant height is required to increase yield in the absence of lodging (Zhang et al., 2017). Higher LAI favors higher grain yield as it increases the photosynthetic area of the plant.

4. Conclusion

Based on the findings of this study it can be concluded that growth parameters, yield attributing traits and yield of rice are significantly affected by various seedling establishment methods. The rice yield ranged from 4.92 tonha^{-1} to 6.13 tonha^{-1} with SRI system producing highest grain yield (6.13 tonha^{-1}) among all the treatments. So, the SRI system could be a better alternative to existing practices to meet the increasing food demand of the rising population in Nepal.

Acknowledgment

The authors would like to acknowledge Mr. Achyut Gairhe, Assistant Professor, IAAS, Rampur Campus for his guidelines and immense support throughout the experiment. They also express deep gratitude to Rampur Campus for providing all the necessary resources.

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