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Response of Rice Establishment Methods on Different Dates on Yield and Yield Attributing Characteristics of Rice in Mid-hills of Nepal

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ABSTRACT

An experiment was conducted in the summer season of 2019 and 2020 at the National Agronomy Research Centre to find out the response of various establishment methods and dates on the performance of rice. The experiment was carried out in 2 Factorial Randomized Complete Block (RCB) design with 3 replications in an area of 12 m^2 and planting geometry of 25 cm between rows and 20 cm between plants. The establishment methods were Sprouted Direct Seeded Rice (SDSR) broadcasting, puddled transplanting, and unpuddled transplanting at three dates viz. 10^{th} June, 26^{th} June, and 10^{th} July. Twenty four hours water-soaked seeds were allowed to sprouting for 48 hours and broadcasted in a puddled plot. 22 days old seedlings were transplanted in a puddled and unpuddled plots. Recommended doses of fertilizer @ 100:30:30 $N:P_2O_5:K_2O$ kg ha^{-1} was used in the experiment. SDSR produced the highest yield of 4.2 Mt ha^{-1} compared to puddled transplanting method with 3.4 Mt ha^{-1}. The highest grain yield was recorded on 10^{th} June (5.9 Mt ha^{-1}) followed by 26^{th} June (4.0 Mt ha^{-1}). Sprouted direct seeded rice permitted to mature early and produced the higher grain yield.

Keywords: Establishment methods, puddle, sprouted, transplanting, unpuddle

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INTRODUCTION

Rice is the major staple food for half of the world's population and it is important to increase its production as the population continues to rise (Roychowdhury et al 2012). The total production of rice in the world is 756,743,722 Mt whereas the total production of rice in Nepal is 5,550,878 Mt with the productivity of 3.8048 Mt ha^{-1} from the cultivated area of 1,458,915 hectares (FAOSTAT 2020).

Rice land ecosystems are categorized into four types: irrigated, rainfed lowland, upland, and deep water rice (also called floating or flood-prone areas) (Greenland 1997, FAO 2020). Irrigated rice covers 55% of the world's rice-growing area and provides 75% of total rice production (Matloob et al 2015). Rainfed lowland rice has a central position in the continuum of rice ecosystems. It is transplanted and grown in leveled, bunded fields that are shallowly flooded with rainwater. It is grown on about 25% of the world's rice area (about 48 million ha) and contributes about 18% of the global rice supply (Svizzero 2021)**.**

Direct seeding and transplanting are the two common methods of rice establishment (Kumar11 Kumar12). Transplanting rice in puddle soil is a tedious method that has a high water requirement for nursery raising and puddling for transplanting. Rice is a water-intensive crop. Puddle transplanting rice cultivation required around 3000 to 5000 L of water for producing 1 kg of rice. Rice is labor intensive crop and contributes to greenhouse gas (methane) emissions under anaerobic conditions (Malhi et al 2021). Puddling makes a thick layer on the upper layer of the soil and minimizes the percolation losses but affects the physical condition of the soil and wastage of time. Transplanting involves seedling preparation in nurseries and replanting in puddle soils (Chen 2007). The benefit of the conventional puddle rice increases nutrient availability in soil basically iron, zinc, and phosphorous, and also reduces the weed population (Surendra et al 2001). The puddle soil creates anaerobic conditions which increase nutrient availability (Sanchez 1973). Traditional transplanting decreasing due to limitations of water and labor. As a result, alternate methods of transplanting should be promoted for enhancing crop and water productivity (Farooq et al 2009; Farooq et al 2011; Datta 1986).

There are three principal methods of DSR in practice. They are dry seeding (sowing dry seeds into dry soil), wet seeding (sowing pre-germinated seeds on wet puddled soils), and water seeding (seeds are sown into standing water) (Farooq et al 2011). In wet seeding (sprouted DSR), pre-germinated seeds (1-3mm radical) are broadcasted (by hand or mechanized blower) or row seeding (drum seeder) in a puddled and leveled soil in aerobic or anaerobic condition. (Balasubramanian and Hill 2002, Joshi et al 2013, Rao et al 2007). Wet DSR is practiced in Malaysia, Thailand, Vietnam, the Philippines, and Sri Lanka due to labor shortage (Pandey et al 2002). Shifting of agricultural labor to non-agricultural sectors, hike in labor prices, and unavailability of labor during cropping season had made problems in rice transplanting. Witnessing this situation, an experiment was designed and conducted at National Agronomy Research Centre Khumaltar, Lalitpur to identify the appropriate rice establishment method.

MATERIALS AND METHODS

Three different establishment methods (Sprouted Direct Seeded Rice (SDSR) broadcasting, puddle transplanting, and unpuddle transplanting) and three dates (June 10, June 26, and July 10) were tested in factorial randomized complete block design with three replications in research farm of National Agronomy Research Centre, Khumaltar, Lalitpur in summer season (June-November) of 2019 and 2020. The soil was silty clay loam (Sand:17.3%, Silt: 57.1%, Clay: 25.6%) with acidic (5.98 pH) in reaction, low in organic matter (2.01%), medium in total nitrogen (0.14%) and high in P_2O_5 (478.8 kg ha^{-1}) and medium in K_2O (160.5 kg ha^{-1}).

Khumaltar lies at 1360 masl with coordinates of 85°10′ E and 27°39’ N latitude. The nursery bed establishment and sprouted seed broadcasting were done on the same day. 22 days old seedling was transplanted in a puddled and unpuddled plot. Two seedlings were transplanted at 25 cm × 20 cm spacing in 4 m × 3m plot. Recommended fertilizers (100:30:30 N:P_2O_5:K_2O kg ha^{-1}) was applied and weeding was done at 30 and 60 DAT. The total precipitation during the crop growing season was 929.9 mm (86 days) in 2019 and 1061.3 mm (83 days) in 2020. Grain yield and straw yield were calculated from the net plot area of 6 m^2. Ten plants were randomly selected for measuring plant height, panicle length, number of filled grains $panicle^{-1}$, and unfilled grains $panicle^{-1}$ at physiological maturity. Crops were harvested from the third week of October to the fourth week of November in 2019 and the first week of November to the fourth week of November in 2020. Thousand-grain weights were recorded from the net plot yield. Grain yield and thousand-grain weight were adjusted at 12% moisture content. Straw samples were sun dried to estimate straw dry matter yield. All the data on yield, yield attributes, and growth parameters were analyzed statistically using IRRI STAR Nebula software, and graphs were drawn using MS EXCEL.

Meteorological Data of Research Years

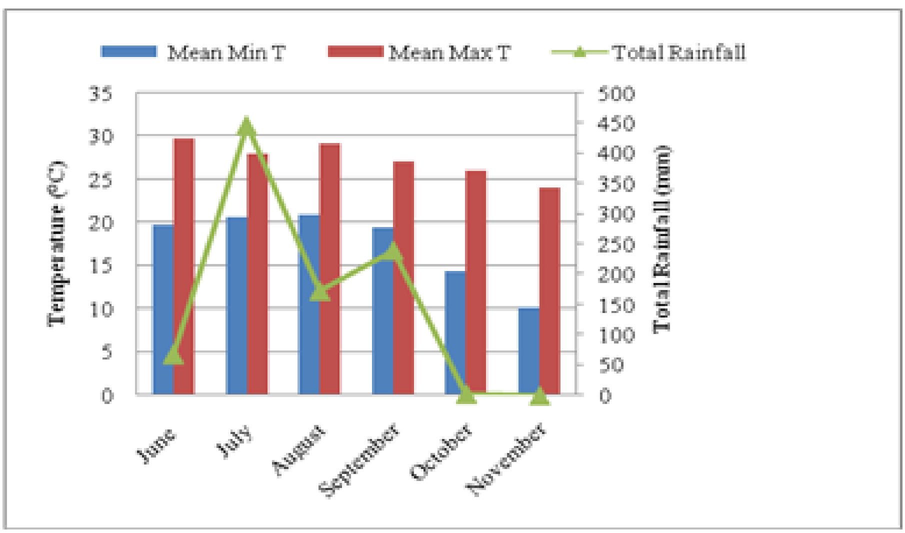

Figure 1. Mean temperatures and the total rainfall during the research period in 2019, Khumaltar

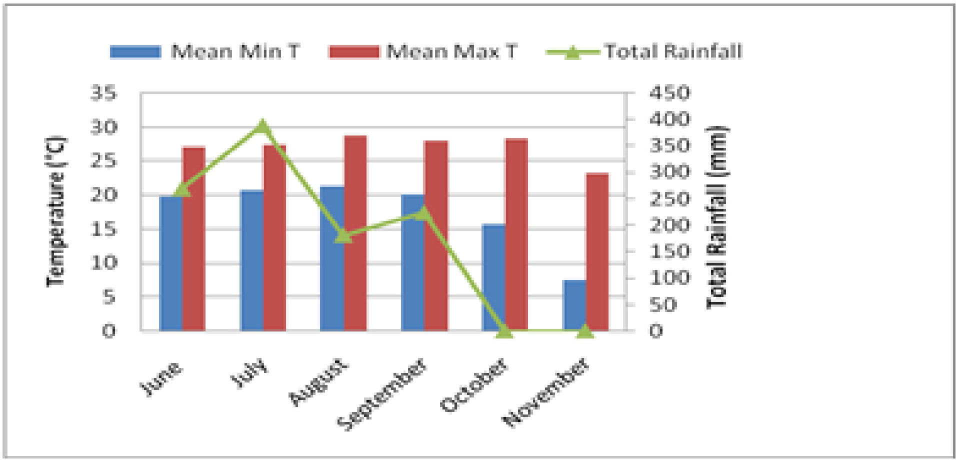

Figure 2. Mean temperatures and the total rainfall during the research period in 2020, Khumaltar

RESULTS AND DISCUSSION

In establishment dates, parameters like days to 50% flowering, days to 90% maturity, plant height, panicle length, number of filled grains per panicle, unfilled grains per panicle, thousand-grain weight, grain yield, and harvest index were found significant while the number of tillers per square meter and straw yield were found non-significant in 2019. In establishment methods, parameters like days to 50% flowering, days to 90% maturity, number of tillers per square meter, grain yield, and harvest index were significant while plant height, panicle length, number of filled grains per panicle, unfilled grains per panicle, thousand-grain weight, straw yield were non-significant in 2019 (Table 1).

In 2020, days to 90% maturity, plant height, number of filled grains per panicle, unfilled grains per panicle, thousand-grain weight, grain yield, biological yield, and harvest index were found significant however traits like days to 50% flowering, number of tillers per square meter, panicle length and straw yield were found non-significant in establishment dates whereas days to 50% flowering, days to 90% maturity, plant height, number of filled grains per panicle, unfilled grains per panicle and grain yield were found significant in establishment methods while the number of effective tillers per square meter, panicle length, thousand-grain weight, biological yield, straw yield, and harvest index were found non-significant in establishment method (Table 2).

Table 1. Yield and yield attributing parameters of rice at different dates and establishment methods at Khumaltar, 2076/77 (2019/20)

Treatments	FD	MD	ET m^{-2}	PH	PL	FG	UG	TGW	GY	SY	HI
Dates (A)											
10 June	93	125	283	161	24.6	166	30	22.3	6.2	9.8	0.39
26 June	96	124	298	142	21.9	136	46	22.0	4.9	10.3	0.32
10 July	96	123	269	131	22.2	27	138	21.2	0.6	11.8	0.04
LSD	3.1	2	ns	22	1.9	23.6	34.0	0.6	0.8	ns	0.07
Establishment method(B)											
SDSR	87	119	329	149	22.8	109	59	21.8	4.4	10.9	0.28
Puddled	99	127	269	141	22.6	103	76	21.6	3.7	11.2	0.24
Unpuddled	99	127	252	144	23.3	117	79	22.1	3.5	9.8	0.22
LSD	3	2	49	ns	ns	ns	ns	ns	0.8	ns	0.07
A*B	0	0	ns	ns	0.0	ns	ns	ns	0.0	ns	0.01
CV (%)	1.9	1	17	15	4.6	21	48	2.8	11.8	30.5	15.40
Grand Mean	**95**	**124**	**283**	**145**	**23.4**	**110**	**71**	**21.8**	**3.9**	**10.6**	**0.25**

FD: days to 50% flowering, MD: days to 90% maturity, ET m^{-2}: number of effective tillers per square meter, PH: plant height (cm), PL: panicle length (cm), FG: filled grains per panicle, UG: unfilled grains per panicle, TGW: thousand grain weight (g), GY: grain yield (Mt ha^{-1}), SY: straw yield (Mt ha^{-1}), HI: harvest index

Table 2. Yield and yield attributing parameters of rice at different dates and establishment methods at Khumaltar, 2077/78 (2020/21)

Treatments	FD	MD	ET m^{-2}	PH	PL	FG	UG	TGW	GY	SY	HI
Dates (A)											
10 June	95	132	259	133	25	165	31	22.1	5.6	6.8	0.45
26 July	97	134	245	125	25	154	42	20.7	3.1	6.8	0.30
10 July	99	130	227	120	25	127	115	20.6	1.2	7.2	0.14
LSD	ns	4.1	ns	7.3	ns	24.4	27.8	1.1	0.6	ns	0.05
Establishment method (B)											
SDSR	90	126	273	132	24	135	53	21.3	4.0	7.3	0.33
Puddled TPR	100	135	235	123	25	161	61	20.9	3.1	6.6	0.29
Unpuddled TPR	99	136	225	123	25	150	74	21.3	2.9	6.8	0.27
LSD	3.4	4.1	ns	7.3	ns	24.4	27.8	ns	0.6	ns	ns
AxB	0	0	ns	ns	ns	ns	0	ns	ns	ns	ns
CV (%)	2.0	1.8	17.7	5.8	4.0	16.4	25.6	5.0	17.1	24.0	19.90
G Mean	**96**	**132**	**244**	**126**	**25**	**149**	**63**	**21.2**	**3.3**	**6.9**	**0.29**

FD: days to 50% flowering, MD: days to 90% maturity, ET m^{-2}: number of effective tillers per square meter, PH: plant height (cm), PL: panicle length (cm), FG: filled grains per panicle, UG: unfilled grains per panicle, TGW: thousand grain weight (g), GY: grain yield (Mt ha^{-1}), SY: straw yield (Mt ha^{-1}), BY: biological yield (Mt ha^{-1}), HI: harvest index

Combined analysis

Date of establishment

Although early date enjoys a better growing environment, days to flowering, days to maturity, number of effective tillers per square meter, and straw yield were found non-significant in the combined analysis. Plant height, panicle length, filled and unfilled grains per panicle, thousand-grain weight, grain yield, and harvest index were significant.

Establishment methods

Days to flowering, days to maturity, number of tillers per square meter, grain yield, and harvest index were found significant in establishment methods. Flowering and maturity were early in sprouted DSR due to easy establishment and absence of transplanting shock. More effective tillers per unit area was recorded in sprouted DSR due to the absence of crop geometry. More effective tillers per unit area contributed to better grain yield and harvest index in sprouted DSR (Table 3).

Table 3 Yield and yield attributing parameters of rice at different dates and establishment methods at Khumaltar, 2077/78 (2020/21)

Treatment	FD	MD	ET m^{-2}	PH	PL	FG	UG	TGW	GY	SY	HI
Dates (A)											
10 June	94	131	266	147	24.9	166	30	22.2	5.9	8.3	0.43
26 June	95	129	272	134	23.4	145	44	21.4	4.0	8.5	0.32
10 July	97	127	248	126	23.8	77	126	20.9	0.9	9.5	0.09
LSD	ns	ns	ns	11.0	1.7	28.2	18.1	0.6	0.85	ns	0.06
Establishment method (B)											
SDSR	87	124	301	141	23.8	122	56	21.5	4.2	9.1	0.31
Puddled	99	131	252	132	23.9	132	70	21.3	3.4	8.9	0.27
Unpuddled	98	131	233	134	24.4	134	75	21.7	3.2	8.3	0.27
LSD	7.1	3.1	31.8	ns	ns	ns	ns	ns	0.85	ns	0.06
A*B	ns	ns	ns	ns	ns	0.04	ns	ns	0	ns	0
CV (%)	4.5	3.5	17.9	12	4.3	18.6	39.8	4	14.3	29.3	18.1
Grand Mean	**95.1**	**128.8**	**261.9**	**135.3**	**24.1**	**129.2**	**66.9**	**21.5**	**3.6**	**8.8**	**0.28**

FD: days to 50% flowering, MD: days to 90% maturity, ET m^{-2}: number of effective tillers per square meter, PH: plant height (cm), PL: panicle length (cm), FG: filled grains per panicle, UG: unfilled grains per panicle, TGW: thousand grain weight (g), GY: grain yield (Mt ha^{-1}), SY: straw yield (Mt ha^{-1}), HI: harvest index

Days to 50% flowering was early in 1st date (10 June) and late in the last date however converse result was observed for maturity days. The establishment date did not affect on no. of effective tillers per square meter. Early established dates produced taller plants and longer panicles due to optimum growth duration while later dates had short growth duration which resulted in shorter plant height and panicle length. An early date had higher filled grains per panicle due to the availability of favorable growing conditions like optimum temperature, moisture, and nutrient management. The last date (10 July) produced merely a few filled grains per panicle due to a lower temperature and less soil moisture in October month. There were two rainy and no rainy days in October which was negligible compared to September. Thousand-grain weights were found highest on 1st date because 10 June established crop exploit all available resources efficiently. Grain yield was significantly higher on 10 June because it was an appropriate time for crop establishment. The straw yield was although non-significant but increased with later dates because of low source-sink conversion in late dates. 10 June had a higher harvest index because of higher grain yield and later dates had a low harvest index due to unfavorable environmental conditions and edaphic factors. Sprouted DSR (wet DSR) showed significant response with days to flowering, days to maturity, effective tillers per square meter, grain yield, and harvest index. Longer establishment duration and absence of crop geometry in sprouted DSR broadcasting allowed the crop to bear more tillers per unit area. Sprouted DSR was early in flowering and maturity. The absence of transplanting shock in DSR resulted in early maturity (7-10 days) which facilitates timely harvest and sowing of subsequent crops (Parthasarathi et al 2012). Shorter land preparation periods for wet seeded rice resulted in 19% less water consumption and 3-17% higher yield (Tabbal et al 2002). The lodging problem is prominent at maturity in wet and water seeding when done at surface level (Balasubramanian and Hill, 2002). Shallow root distribution and shallow depth of buried culm base are the major lodging-inducing factors in broadcasted rice (Lee et al 2002a). High amounts of N application also increase field lodging (Lee et al 2002b). Lodging results in a sizable reduction in grain yield due to decreased photosynthesis by self-shading, reduced grain size, and hampers grain quality (Liu et al 2014). Proper irrigation management reduces the incidence of lodging. Sprouted DSR is the best alternative to puddle transplanting if proper crop management is done.

CONCLUSIONS

Conventional method of rice growing is tedious, labour and water intensive. Sprouted DSR reduces drudgery, allows crop to establish early, longer growth duration and produce more grain yield. Sprouted direct seeded rice yielded 4.2 Mt ha^{-1} compared to puddle and unpuddled transplanting. Similarly, crop established on 10^{th} June produced highest grain yield of 5.9 Mt ha^{-1}. From our experiment, we conclude that sprouted DSR is better option over puddle transplanting when timely management is done.

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AUTHORS' CONTRIBUTION

Mr. B. Chaulagain was responsible for project development, field layout, research execution and manuscript writing. Mr. Bhattarai gave valuable inputs beginning from project proposal to data analysis. Mr. Gyawaly helped with data analysis and paper write-up. Mr. Karki reviewed the article before sending it to an external reviewer and gave valuable suggestions and inputs.

CONFLICTS OF INTEREST

The authors have no any conflict of interest to disclose.

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