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Modified Nursery Structures: An Approach to Grow Rice Seedlings in Winter for Early Spring Planting

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ABSTRACT

Raising rice seedlings in cold winter months for subsequent early spring transplanting has a great challenge in rice-rice cropping system in Nepal. An essential technological intervention involves modifying the rice nursery structure to create an optimal environment that supports proper germination and seedling growth during the cold season. Hence, a field experiment was conducted to evaluate the impact of different nursery structures on the germination and growth of rice seedlings in the farmer's field at Sunwal-12, Bhumahi, Nawalparasi West, from 21st of January- 19th of February, 2021, 2021. The experiment was executed in randomized complete block (RCB) design with 8 different raised bed (1m × 1m) structures as treatments, namely T_1: open uncovered beds, T_2: plastic tunnel covered beds, T_3: mat bed under plastic tunnel, T_4: plastic trayunder plastic tunnel, T_5: Plastic tray under open condition, T_6: Open bed with removal of dew, T_7: Ash covered beds and T_8: Plastic sheet covered beds. Each treatment was repeated three times. The spring rice variety Chaite-5 was sown at the rate of 60 g m^{-2}, with dry seeds being evenly distributed in rows spaced 10 cm apart. The beds were fertilized at the rate of 1 kg N, 0.8 kg P_2O_5 and 0.8 kg K_2O 100 m^{-2}. Soil temperatures at a depth of 5 cm were monitored regularly at two time points each day, specifically at 8 am and 4 pm, until 30 days after sowing (DAS). The results revealed that the germination index, average height, and above ground weight were significantly higher (40.57, 9.81 cm and 78.67 gm^{-2}, respectively) for the beds under tunnel (T_2). Seedlings grown in trays under tunnel exhibited statistically similar plant heights. The highest seedling population m^{-2} (288% more compared to open beds) was obtained in trays (both open and under tunnel). Trays and mat beds under tunnel recorded higher soil temperature in the morning and evening, as well as higher air temperatures and relative humidity. These favorable conditions were met approximately 16-17 days earlier compared to the uncovered beds. Therefore, the practice of covering seedling beds with plastic tunnels, growing rice seedlings in plastic trays and utilizing mat beds were the better ways for raising rice seedlings in cold environments for early spring transplanting.

Keywords: Nursery beds, tunnel, spring rice, temperature

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INTRODUCTION

Rice-based cropping systems are the most productive agro-ecosystems in Asia and produce the food for the most people. Globally, rice is produced in 165.25 million ha with the production of 502.98 million tons among which top 10 major rice producers are Asian countries, China being the leader (Shahbandeh 2023). Asia alone contributes 90.70% of the total global production of rice (FAOSTAT 2017). Rice is food for global population and its production is crucial in ensuring food security and livelihood in Indo-Gangetic Plain (Kumar et al 2018). Rice, the major staple food of Terai and inner terai alone covers 70.50% of the total cultivable land with the productivity of 3.82 t ha^{-1} (MoALD 2021). Rice is the most important cereal crops in agriculture and economy of Nepal contributing 12 percent to gross domestic product (Spotlight online 2020). About 75% of the working population is engaged in rice farming for at least six months of the year. About 92 percent of rice area falls under main (*Barkhe*) season while 7 percent is under spring (*Chaite*) season (MoAD 2015). Rice-rice cropping system is predominant in the Plain (Terai) where there is facility of irrigation during spring season.

The food security of Nepal depends on the production of major staples. The annual demand of milled rice is estimated at 4.08 million tons against a production of 3.25 million tons of milled rice (Choudhary et al 2022). To meet the demand without any additional land, the best way is to adopt rice-rice cropping system in which main season rice is cultivated after the harvest of spring season rice. Commonly, spring rice is sown in the last week of February to the first week of March and follows transplanting of 30-40 days old seedlings. This crop also needs assured irrigation from various sources. The national area coverage of spring rice is 112,000 hectares, with the distribution across mountain, hill, and Terai regions being 5.48%, 24.85%, and 69.67%, respectively (Dangi 2021). In Nawalparasi, about 666 ha of land is cultivated with spring rice with the production of 3397 tons and productivity of 5.10 tha^{-1} and 22712 ha of land with production of 101066 tons and yield of 4.45 t ha^{-1} under rainy season rice (MoALD 2021).

The global rice production is being shrunk due to adverse weather events from China to South Asia and California who suffered from damaged harvest and has also been aided by the ongoing Russian invasion to Ukraine. The grain's stock-to-use ratio, a major indicator of supply availability has become lowest in five years (Gro Intelligence 2022) but the global rice demand is increasing (FAO 2022). Hence, to meet the global and domestic demands of rice, with the limited land, adoption of rice-rice cropping system is one of the best alternatives.

In the context of a double rice cropping system, the preparation of seedlings in nurseries during the colder months and in order to combat the cold stress is a significant challenge. To mitigate the effect of this stress and ensure the production of healthy seedlings, the various techniques can be used. The seedlings can be grown under the plastic tunnels, or plastic cover. Rapid seed germination and successful stand establishment are crucial factors for crop production, particularly under cold stress conditions (Reddy et al 2018). One potential approach to enhance rice seedling establishment might be the structural modification of nursery. Seedling intended for early spring planting need to raise in December and January during when they are exposed to severe cold temperatures. The low air and water temperatures during cool season are the major causes of seedling mortality. To address this issue, suitable nursery management techniques must be developed to ensure stable rice production. To increase the soil and air temperature in the nursery beds, the beds can be covered with transparent polythene (Bodapati et al 2005). The establishment of the seedlings in the field is closely linked to seedling vigor, indicated by factors such as leaf number, biomass production, germination rate, and height. Structural modifications that positively impact rice seedling establishment based on these criteria represent a highly desirable technological intervention for farmers engaged in double rice cropping systems, leading to the initiation of this field experiment.

MATERIALS AND METHODS

Site Description

The experiment was conducted at the farmers field at Sunwal-12, Bhumahi, Nawalparasi West, which lies in humid subtropical inner Terai region of Nepal during 21st January – 19th March, 2021. The soil in the experimental field was clay with slightly acidic to neutral pH, medium to low OM and nitrogen content, high phosphorus and medium potassium content according to the standard rating of Government of Nepal, Kathmandu.

Experimental Design and Treatments

The experiment was laid out in simple RCB design with three replications, encompassing eight treatment conditions: T_1: Open uncovered beds, T_2: Plastic tunnel covered beds, T_3: Mat bed under plastic tunnel, T_4: Plastic tray under plastic tunnel, T_5: Plastic tray under open condition, T_6: Open bed with removal of dew, T_7: Ash covered beds and T_8: Plastic sheet covered beds, with each treatment being replicated three times. The raised nursery beds, measuring 1 m × 1 m, were prepared. For the plastic tunnel related treatments (T_2, T_3,T_4), bamboo frames were used to create a transparent plastic dome utilizing a 500 GSM plastic sheet to cover it. The dome's central height was maintained at 50 cm. In the case of treatments T_4 and T_5, the plastic trays (58 cm × 28 cm × 2.25 cm) were utilized. These trays were cleaned and filled with a uniform layer of dry soil (1.3 cm), and dry seeds were sown at a rate of 60 g m^{-2} in six rows spaced at 5.8 cm and was covered by dry soil layer up to the height of tray (2.25 cm) whereas 10 rows spaced at 10 cm were formed for the remaining treatments and dry seeds were uniformly sown @ 60 g m^{-2}.Water was sprinkled on traysafter seedbed preparation and kept in the open raised beds or under the tunnel depending on the treatment and the other beds were also irrigated.For treatment T_8, the bed was covered with transparent plastic sheet (500 GSM) and after germination of seedlings, the plastic was raised at four corners using bamboo pegs to a height of 30 cm. The seed rate was also kept as 60 g m^{-2} for all the remaining beds. Regarding the mat seed bed (T_8), 2.5 cm thick soil layer was spread over the perforated plastic sheet kept on the prepared seed bed and then seed was sown and covered with fine layer of soil. The daily temperature at 5 cm depth was recorded at 8 AM and 4 PM.

The field was deep tilled and then pulverized and leveledduring mid-January. The dry beds of 1m×1m area and rose at 15 cm from surface were made. Adequate nutrients at the rate of 1 kg N, 0.8 kg P_2O_5 and 0.8 kg K_2O per 100 m^{2}were applied uniformly to nursery beds to avoid the effect of nutrient deficiency on seedling growth

Sampling and Measurements:

For the analysis of seedling, various data were recorded which are:

a. **Germination index:** GI = no. of germinated seed/days of first count + ... + no. of germinated seed/days of last count

b. No. of seedlings per sq. meter = The number of seedlings germinated and grown wasassessed with the area of 50 cm ×10 cm area (20 × 5.8 cm in case of tray grown seedlings) and expressed in m^{-2}.

c. Seedling height: The height of 10 seedlings was taken randomly measuring from the surface of soil to the uppermost leaf after 30 DAS.

d. Seedling biomass: The biomass of seedlings from 50 cm × 10 cm area (20 × 5.8 cm in case of tray grown seedlings) was recorded. The plants were uprooted and the above ground plant parts were weighed and dried in oven for measuring the biomass and finally converted in per sq.meter.

e. Soil temperature: The temperature of each nursery bed at a depth of 5 cm was measured using soil thermometer during the course of nursery establishment at 8 AM in the morning and 4 PM in the afternoon. The temperature was averaged for three consecutive days and was subjected to paired t-test.

f. Ambient temperature and relative humidity: The temperature and relative humidity of the open environment and inside the tunnel was recorded at 8 AM in the morning and 4 PM in the afternoon. The temperature and RH inside and outside the tunnel were averaged for each five consecutive days and was subjected to paired t-test.

Statistical Analysis

The data were subjected to analysis of Variance, and Duncan's Multiple Range Test at a 0.05 level of significance for mean separations (Gomez and Gomez 1984). Dependent variables were subjected to analysis of variance using the R-Studio for RCB design.

RESULTS AND DISCUSSION

Growth of seedlings

The growth of rice seedlings grown under various modified nursery structures was assessed through the observations including Average height, above ground dry matter (AGDM), germination rate index and seedling population.

Table 1. Average height (cm), above ground dry matter (g m^{-2}), germination rate index and seedling population (m^{-2}) of rice seedlings at 30 DAS as influenced by different nursery structures at Bhumahi, Nawalparasi West during 2021

Treatments	GRI	Seedlings (m^{-2})	Average height (cm)	AGDM (gm^{-2})
Open uncovered beds (T_1)	3.28^{d}	873.33^{c}	7.35^{c}	12.93^{c}
Plastic tunnel covered beds (T_2)	36.96^{a}	1486.67^{b}	9.81^{a}	78.67^{a}
Mat bed under plastic tunnel (T_3)	20.46^{b}	1226.67^{bc}	8.98^{ab}	49.07^{b}
Plastic tray under plastic tunnel (T_4)	15.88^{bc}	2518.52^{a}	9.37^{a}	82.67^{a}
Plastic tray under open condition (T_5)	2.81^{d}	2400^{a}	8.08^{bc}	46.37^{b}
Open bed with removal of dew (T_6)	4.98^{cd}	1053.33^{c}	8.11^{bc}	20.87^{bc}
Ash covered beds (T_7)	2.29^{d}	873.33^{c}	7.79^{c}	16.93^{c}
Plastic sheet covered beds (T_8)	20.30^{b}	1206.67^{bc}	9.52^{a}	46.53^{b}
SEm (±)	0.48	16.254	0.045	1.129
LSD (0.05)	11.61***	394.40***	1.08**	27.40***
CV (%)	39.01	15.48	9.11	35.36
Grand mean	16.99	1454.82	8.93	44.26

Notes: ***, significant at <0.01 level; GRI, germination rate index; AGDM, above ground dry matter. Treatment means followed by the common letter (s) are not significantly different among each other based on DMRT at a 0.05 level.

The germination rate index was significantly higher for plastic tunnel covered beds followed by mat bed under tunnel and plastic sheet covered beds which were statistically at par with each other. The lowest germination rate index (2.81) was obtained in plastic trays in open condition, ash covered beds (2.29), and in open raised bed (3.28). The highest population of seedlings per square meter in plastic tray under tunnel (2518.52 m^{-2}) was found to be 188% more compared to seedling population in open beds. All the plastic tunnel covered beds and plastic sheet covered beds have statistically similar seedling population.

The seedling height was significantly taller in plastic tunnel covered beds, plastic tray under tunnel and plastic sheet covered beds and statistically at par with the height of seedlings in mat beds under plastic tunnel. The height of seedlings grown under plastic tunnel covered beds were about 33% more compared to the height of seedling grown under open condition. Seedling dry weight was significantly higher for beds under tunnel and plastic trays under tunnel. The higher seedling dry weight is attributed to higher germination index, higher number of seedlings per square meter and taller seedling height.

Soil Temperature during morning and afternoon

The average soil temperature in the various nursery structures ranged from 11.33˚C to 16.28 ˚C during the growth of seedling (Table 2) and afternoon temperature ranged from 18.03˚C to 21.54˚C (Table 3). These variations in temperature reflect the diverse microclimates created by the different nursery structures. The morning soil temperatures of various nursery structures were significantly different from 4-21 days of seedling growth. The highest morning and afternoon soil temperatures were observed in tunnel T_2, T_3, T_4, and T_8. This result suggests that these structures effectively trapped heat and created a warmer microenvironment for the seedlings. Warmer soil temperatures are favorable for promoting faster germination and more robust seedling growth. In contrast, beds that were left open (i.e. T_1, T_5, T_6 and T_7) recorded significantly lower morning and afternoon temperature (Table 2 and 3). This lower temperature range may have contributed to less optimal conditions for seedling development. Cold stress during the early stages of growth can lead to slower germination rates and reduced seedling vigor. Seedlings rose under tunnel-covered beds and plastic sheet-covered beds benefitted from the higher soil temperatures, both in the morning and afternoon (Table 1, 2, and 3). These conditions likely facilitated faster germination and provided a more conducive environment for overall seedling development.

Table 2. Morning soil temperature (average of three consecutive days) at 8 am as influenced by different nursery structures at Bhumahi, Nawalparasi West during 2021

Treatment	**Average temperature (˚C)**									
	0-3 DAS	**4-6 DAS**	**7-9 DAS**	**10-12 DAS**	**13-15 DAS**	**16-18 DAS**	**19-21 DAS**	**22-24 DAS**	**25-27 DAS**	**28-30 DAS**
T_1	13.00	13.28^{c}	10.78^{cd}	11.39^{cd}	9.78^{de}	11.66^{de}	13.72^{bcd}	14.67	16.06	15.67^{b}
T_2	13.85	15.22^{a}	12.17^{ab}	13.05^{a}	12.39^{abc}	13.44^{ab}	15.39^{ab}	16.61	17.00	18.11^{a}
T_3	13.52	14.45^{a}	12.28^{ab}	12.50^{abc}	12.50^{ab}	12.81^{bc}	15.28^{ab}	15.89	16.39	16.00^{b}
T_4	13.56	14.11^{ab}	11.06^{bc}	12.89^{a}	13.61^{a}	14.06^{a}	16.72^{a}	16.8	17.39	17.06^{ab}
T_5	13.46	12.39^{d}	9.61^{d}	10.78^{d}	11.05^{cd}	11.06^{e}	12.67^{d}	14.67	15.00	15.78^{b}
T_6	13.05	13.34^{c}	11.02^{bc}	10.89^{d}	9.50^{e}	12.00^{cd}	13.50^{cd}	15.06	15.78	15.56^{b}
T_7	13.43	13.83^{bc}	11.17^{bc}	11.61^{bcd}	9.89^{de}	12.39^{cd}	13.11^{d}	14.06	15.22	15.61^{b}
T_8	13.47	14.94^{a}	12.55^{a}	12.78^{ab}	12.11^{bc}	13.39^{ab}	14.94^{bc}	15.39	16.11	16.44^{b}
SEm (±)	0.04	0.032	0.051	0.048	0.053	0.035	0.068	0.080	0.060	0.055
LSD (0.05)	ns	0.79***	1.24**	1.16**	1.29***	0.86***	1.63**	ns	ns	1.34*
CV (%)	4.18	3.22	6.26	5.50	6.48	3.88	6.49	7.13	5.46	4.71
Grand mean	13.41	13.95	11.33	11.98	11.35	12.60	14.41	15.40	16.12	16.28

Notes: T_1, Open uncovered beds; T_2, Plastic tunnel covered beds; T_3, Mat bed under plastic tunnel; T_4, Plastic tray under open condition; T_5, Plastic tray under plastic tunnel; T_6, Open bed with removal of dew; T_7, Ash covered beds; T_8, Plastic sheet covered beds. Same letter(s) within column represent non-significant difference at a 0.05 level based on Duncan multiple range test. DAS, days after sowing; *, **, *** represent significant at 0.5, 0.1, 0.01 level respectively.

Table 3. Afternoon soil temperature (average of three consecutive days) at 8 am as influenced by different nursery structures at Bhumahi, Nawalparasi West during 2021

Treatment	Average Temperature (˚C)									
	0-3 DAS	4-6 DAS	7-9 DAS	10-12 DAS	13-15 DAS	16-18 DAS	19-21 DAS	22-24 DAS	25-27 DAS	28-30 DAS
T_1	17.50^{b}	16.06^{cd}	13.33^{d}	14.83^{c}	17.94^{c}	16.94^{c}	20.00^{bc}	19.22^{cd}	20.67^{b}	20.56^{c}
T_2	19.29^{a}	19.00^{a}	15.78^{ab}	17.83^{a}	21.22^{ab}	20.06^{b}	21.61^{ab}	21.28^{bc}	22.56^{a}	22.61^{a}
T_3	19.25^{a}	19.11^{a}	16.00^{ab}	18.50^{a}	23.00^{a}	19.67^{b}	21.11^{abc}	20.39^{bcd}	22.50^{a}	21.17^{bc}
T_4	18.81^{a}	18.89^{a}	15.44^{b}	18.11^{a}	23.06^{a}	22.61^{a}	23.22^{a}	24.94^{a}	22.78^{a}	22.44^{ab}
T_5	16.28^{b}	15.17^{d}	12.17^{e}	15.78^{bc}	18.78^{c}	19.06^{b}	20.61^{bc}	22.44^{b}	22.44^{a}	22.17^{ab}
T_6	17.00^{b}	16.61^{bc}	13.50^{d}	15.17^{c}	18.94^{c}	17.17^{c}	18.89^{c}	18.61^{d}	20.56^{b}	20.72^{c}
T_7	17.09^{b}	17.00^{b}	14.33^{c}	15.72^{bc}	18.83^{c}	16.33^{c}	19.17^{bc}	18.83^{d}	20.56^{b}	21.5^{0abc}
T_8	19.04^{a}	18.78^{a}	16.28^{a}	17.22^{ab}	20.89^{b}	19.28^{b}	21.06^{abc}	20.94^{bcd}	21.78^{ab}	21.17^{bc}
SEm (±)	0.023	0.037	0.029	0.060	0.078	0.060	0.092	0.088	0.060	0.051
LSD (0.05)	1.23***	0.90***	0.70***	1.46***	1.89***	1.46***	2.22*	2.14***	1.46*	1.25*
CV (%)	3.90	2.94	2.73	5.01	5.31	4.42	6.14	5.87	3.83	3.32
Grand mean	18.03	17.60	14.60	16.65	20.33	18.89	20.71	20.83	21.73	21.54

Notes: T_1, Open uncovered beds; T_2, Plastic tunnel covered beds; T_3, Mat bed under plastic tunnel; T_4, Plastic tray under open condition; T_5, Plastic tray under plastic tunnel;T_6, Open bed with removal of dew;T_7, Ash covered beds; T_8, Plastic sheet covered beds. Same letter(s) within column represent non-significant difference at 0.05 level of significance based on Duncan multiple range test. *,**,*** represent significant at 0.5,0.1,0.01 level of significance.

Ambience of growing environment

The nursery structures under tunnel had created optimal growing environment characterized by increased temperatures and relative humidity, especially during cold seasons. Table 4 demonstrates a significant difference in both morning and afternoon ambient temperatures inside and outside the tunnel. Furthermore, relative humidity levels are consistently higher within the tunnel structures. These conditions create a microenvironment that is conducive to seedling growth and development.

As we find the growing environment in the beds covered with tunnels and plastic cover and in plastic trays, the seedling growth is better. The low air and water temperatures during cool season pose significant challenges in the seedling survival. The modification made in T_2, T_3, T_4 and T_8 help overcome these challenges, as suggested by the previous research of (Bodapati et al 2005). The ability of these structures to maintain higher soil, water, and air temperatures is critical in mitigating cold stress, a known factor contributing to seedling mortality. Previous research studies have also indicated the benefits of such protected nursery environments. (Shah et al 2000) found that low tunnel polythene-covered nurseries maintained higher temperatures across various elements, including soil, water, and air, compared to conventional methods. This elevated temperature has been shown to foster the production of heavier seedlings. (Tang and Zhang 1993) as cited in Bodapati et al 2005) also reported advantages of growing rice seedlings under greenhouse conditions. Their research indicated that the controlled environment within the cover provided more favorable temperature, humidity, and light intensity compared to the outside atmosphere.

In this study, seedlings in the modified beds under tunnels and plastic cover gained a total of 478.4 GDD, while those in open conditions gained 383.6 GDD (calculating the mean temperature from morning and afternoon readings as shown in Table 3 and 4). This indicates that seedlings in the modified structures accumulated more heat units, which aligns with the findings of (Wilson et al 2000). Higher GDD values are associated with improved seedling performance, as they contribute to a more robust Germination Rate Index (GRI), greater seedling numbers, and increased biomass production. The positive association between higher GDD and increased seedling biomass production is a reflection of the benefits of a warmer and more consistent thermal environment. When seedlings are exposed to higher GDD conditions, several physiological processes are optimized, leading to greater biomass accumulation. Elevated temperatures, correlated with higher Growing Degree Days (GDD), stimulate faster metabolic processes in seedlings, leading to accelerated growth and increased biomass accumulation. These elevated temperatures enhance photosynthesis efficiency, boosting carbohydrate production and contributing to greater biomass. Adequate thermal conditions reduce stress on seedlings, as in colder environments, energy is diverted towards coping with cold stress rather than growth.

Higher GDD helps mitigate this stress, enabling seedlings to allocate more resources to biomass production. (Dong et al 2009) also found out that soil temperature increased significantly in plastic mulch plots compared to the non-mulched ones and this increased temperature is responsible for better germination, growth and biomass of the seedlings.

Table 4. Comparison of average ambient environment condition outside and inside tunnel for various nursery structures at Bhumahi, Nawalparasi West during 2021

Ambient environment	**0-5 DAS**	**6-10 DAS**	**11-15DAS**	**16-20 DAS**	**21-25 DAS**	**26-30 DAS**	**31-35 DAS**	**36-40 DAS**
Morning Temperature								
Inside	14.86	14.42	16.04	18.90	18.70	19.32	22.62	27.10
Outside	13.84	12.86	14.10	17.42	17.44	16.35	20.14	21.72
Mean Diff.	1.02**	1.56*	1.94**	1.48	1.26*	2.97	2.48*	5.38
t-value	-6.40	-3.71	-6.52	-1.96	-3.75	-1.58	-3.52	-3.20
p-value	0.003	0.02	0.003	0.121	0.020	0.189	0.024	0.032
Afternoon Temperature								
Inside	20.32	15.92	26.02	22.74	27.18	27.20	26.64	29.68
Outside	17.24	14.72	20.70	21.26	25.38	26.12	23.98	26.42
Mean Diff.	3.08*	1.20**	5.32*	1.48	1.80	1.08	1.66*	3.26
t-value	-3.89	-4.74	-3.75	-1.83	-2.58	-2.53	-3.19	-2.14
p-value	0.018	0.009	0.020	0.142	0.061	0.065	0.033	0.099
Morning Relative Humidity								
Inside	89.60	90.40	94.20	83.00	83.40	76.40	83.40	81.20
Outside	86.20	81.60	87.20	78.40	75.40	73.20	73.00	80.60
Mean Diff.	3.40	8.80*	7.00	4.60	8.00*	3.20*	10.40***	0.6
t-value	-2.21	-3.123	-1.82	-1.15	-3.00	-3.14	-10.10	-0.100
p-value	0.091	0.035	0.140	0.32	0.040	0.034	0.0005	.0920
Afternoon Relative Humidity								
Inside	92.80	91.60	64.20	75.40	81.00	71.40	68.00	63.80
Outside	74.60	74.80	63.00	66.00	65.80	63.60	60.00	59.60
Mean Diff.	18.20**	16.80*	1.4	9.4**	15.20	7.80	8.00*	4.20
t-value	-5.45	-3.611	0.37	-4.67	-2.76	-2.13	-3.00	-1.22
p-value	0.006	0.022	0.733	0.009	0.051	0.101	0.040	0.291

Notes: DAS, Days after sowing. *,**,*** represent significant at 0.5,0.1,0.01 level of significance.

Possibilities of early seedling raising

The figure 1 shows that the average temperature inside the tunnel during first 1-5 days after sowing was similar with the temperature outside the tunnel at 15 DAS. This similarity in ambient temperature indicates that the growing environment for the seeds inside the tunnel is comparable to the conditions outside. Table 1 indicates that the seedlings grow better under tunnel conditions. This suggests that modifying nursery beds to create tunnel-like environments can lead to improved seedling growth. Due to the similarity in growing conditions and the improved seedling growth under tunnel conditions, it is expected that seedlings can be obtained 16-17 days earlier than traditional methods and it would be possible to transplant rice in third week of February instead of first fortnight of March. This early seedling production has significant implications for rice-rice cropping system to preponed the transplanting of spring rice. The spring planted early produces higher yield (Ferrer et al 2022). The higher seedling population (table 1) indicated the better resource use efficiency for seed and satisfactory seedlings can be obtained from the sown seeds and the cost for seed can also be reduced. The higher dry matter production and longer seedling production under plastic tunnel covered beds i.e. T_2, T_3, T_4, T_8 indicated the production of vigorous seedlings which hastens crop establishment under transplanted condition. Similar relation between the seedling vigor and seedling establishment in field has been explained by (Yamauchi and Winn 1996). The longer seedlings also aid in transplant operation.The early seedling raising leads to early transplanting and consequently facilitates the farmers to harvest the spring rice in pre-monsoon time. During the time, the harvesting would be easier due to direr field, and there will be plentiful labor supply as the rice transplanting wouldn't have been initiated. The rice straw won't be muddy and can be used as feed for the livestock and also can be used for making silage because of the green nature of straw.

The comparative illustration of morning ambient temperature inside and outside tunnel is as follows:

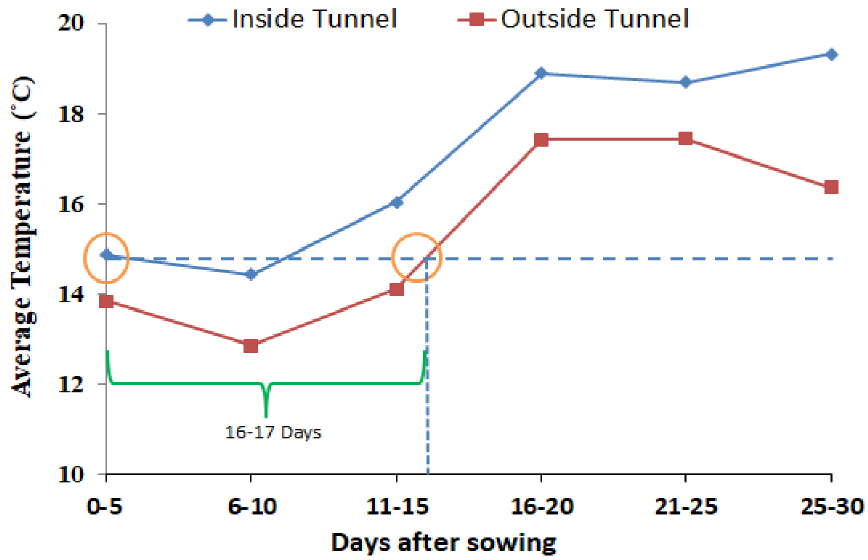

Figure 1: Schematic representation of time for the occurrence of similar average morning temperature (˚C) outside tunnel as that of initial average morning temperature (˚C) inside tunnel

Conclusions

Utilizing tunnel covers, plastic sheets, or trays under tunnel for nursery beds enhance the germination rate index, seedling population per square meter, and vigor of seedling. These modifications provided warm growing conditions by approximately two weeks compared to normal conditions which gave an opportunity to grow seedlings during colder days and greatly facilitate the early transplanting of rice seedlings. Such innovative approaches offer promising prospects for optimizing rice farming practices and improving crop yields.

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AUTHORS' CONTRIBUTION

Puspa Raj Dulal in consultation with Santosh Marahatta, Shrawan Kumar Sah and Lal Prasad Amgain, formulated the research proposal, carried out the experiment, collected the data, and prepared ANOVA and manuscript. S Marahatta, SK Sah and LP Amgain, guided him in all aspects but particularly in the statistical analysis, and write-up of the manuscript.

CONFLICTS OF INTEREST

The authors have no any conflict of interest to disclose.

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