GRAIN YIELD AND AGRO-CLIMATIC INDICES OF RICE CULTIVARS TRANSPLANTED IN DIFFERENT DATES IN MID-WESTERN TARAI, NEPAL

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ABSTRACT

An experiment was conducted to assess the productivity and agro-climatic indices of different rice cultivars under staggered transplanting dates in farmers' field at Lamahi, Dang during May to November 2018. The experiment was laid in a two factorial randomized complete block design with 9 treatments and 3 replications. Two factors included were: three rice cultivars; Arise-6444, Sarju-52, and Sukkha-3, and three transplanting dates; 19th June, 29th June, and 9th July. Phenological observation and yield attributing characters were recorded and statistical analysis was done. Cultivars under different transplanting dates showed significant variation in yield, yield attributes, and agro-climatic indices, individually and in interaction. Variety Arise-6444 attained early booting, panicle initiation, heading and flowering followed by Sukkha-3 and Sarju-52, respectively. Cultivar Arise-6444 showed the highest panicle weight (4.84g), effective tillers m^{-2} (242), grains panicle^{-1} (201) and grain yield (9213 kg ha^{-1}). Early transplanting brought the phenological stages late as compared to mid and late transplanting. Cumulative GDD and PTI were significantly higher in Sarju-52 being 2066 and 15.90, respectively, whereas Arise-6444 showed the highest HUE (4.702). Irrespective of transplanting dates, early transplanting exhibited the highest GDD (2150.76) and PTI (16.36). Early transplanting of Sarju-52 showed the highest GDD (2211) while the highest PTI (16.59) was recorded in early transplanting of Arise-6444. Thus, varieties having high HUE should be planted early for better yield and to cope with the adverse effect of climate change.

Keywords: *GDD, grain yield, rice, phenology, yield attributes*

INTRODUCTION

Rice is the most important staple food crop and ranks first among cultivated cereal crops both in terms of area (1,552,469 hectare) and production (5,230,327 metric tons) in Nepal (AICC, 2018). Rice shares 42.5% of the total area under food grains and 51.6% of total food grain production with 18% contribution to the AGDP and 7% to GDP of Nepal (Bastola et al*.,* 2020). Rice is cultivated in a wide range of ecology from Terai and inner-Terai to high hills under irrigated, rainfed lowland and upland production environment (MOAD, 2018). The Terai region is the major hub for the production of rice as 70% of the total rice is produced in this region, while the hills and mountain contribute 26% and 4%, respectively (Adhikari et al., 2018). In Dang District, rice occupies an area of 38,100 hectares with the production of 152,400 metric tons and the productivity of 4 metric tons/ha (MoAD, 2018). Farmers of Lamahi, Dang cultivate both hybrid and improved varieties of rice due to their better production over local variety. However, the local cultivars are also common in the area. The three rice cultivars namely Arize-6444 (hybrid), Sukkha-3 (improved) and Sarju-52 (local) used in this experiment are the most preferred varieties in Lamahi area by the farmers for different desirable traits, performance, and wider adaptability (AICC, 2019).

Majority of rice farming in Nepal is rainfed (80%), which limits the farmers to transplant the crop on time ultimately reducing the yield (NARC, 2009). Seedling age at the time of transplanting is an important factor for the uniform crop stand. Among the crop production methods, proper transplanting dates and method are the pre-requisites that enable the crop to complete its life process in a timely and productive manner under a specific agro-ecology (Vange & Obi, 2006; Bashir *et al*., 2010). Rice planted before the optimum date usually has slow germination and development, poor establishment, seedling diseases under cold conditions and seed loss by birds or mice (Linscombe *et al.,* 2004). After optimal date, rice planting may result in low yield due to higher disease and insect occurrence, tropical storm, lodging and potential heat or cold damage during heading and grain filling time (Groth & Lee, 2003; Osman *et al.,* 2015). Similarly, if the age of seedlings is not optimum, because of the reduction in vegetative time, the seedlings generate less tillers and hence results in low yield. Likewise, the growth and development of a crop is passed by several phenological stages and each stage has its own physiological significant. The growth phases of any variety of crops are determined basically by growing season in which the ambient temperature and solar radiation are the major governing factors (Rao & Singh, 2007). Likewise, Becker *et al.* (1999) reported that due to rainfed conditions, farmers cannot predict the transplanting time, and they are forced to transplant the old aged seedlings.

Transplanting time of rice crop is important for different reasons as it ensures that vegetative growth occurs during a period of satisfactory temperatures, high levels of solar radiation and water table. Moreover, it ensures that the cold sensitive stage occurs when the minimum night temperatures are the warmest and it guarantees that grain filling occurs when milder autumn temperatures are more likely, for a good grain quality (Farrell *et al.,* 2003). Despite being aware of the significance of timely transplanting, farmers are still in dilemma as to which varieties will provide greater yield under prevailing environment. The existing varieties being cultivated do not appear to be well adapted for good growth and yield (Beeker *et al*., 1999, Thapa & Bhusal, 2020). Thus, there is a need to study the performance of hybrid, improved and local varieties at different transplanting times. Weather variability is considered as one of the major factors of inter-seasonal variability of crop growth and yield in all the environments. Besides, rainfall, temperature and optimum sunshine hours also have bearing on crop growth and development as well as yield response of different species to different environments can be quite variable. Shift in transplanting dates directly influences both thermo and photo period, and consequently has great impact on the phasic development and partitioning of dry matter (Patel *et al.,* 2019). Hence, the knowledge on the calculation of the Growing Degree Days (GDD) and their further mathematical derivations like Pheno Thermal Index (PTI) and Heat Use Efficiency (HUE) are the basic principles to understand the phenology and the proper planting times for different crop varieties over the spatial and temporal variations (Sreenivas *et al.,* 2010). Thus, it is vital to understand how the time of transplanting and use of varieties affect the agro-climatic indices in rice. Therefore, this research was conducted to assess the productivity and agro-climatic indices of different rice cultivars grown under staggered transplanting dates; to determine the suitable age of seedling for transplanting; and to determine the most suitable rice cultivar for Lamahi area in Mid-Western Terai, Nepal.

MATERIALS AND METHODS

The experiment was conducted at Lamahi, Dang from May to November, 2018 in farmer's fields. The site was situated at an elevation of 567.29 meters above mean sea level, 27°86'73" North latitude and 82°54'74" East longitude with neutral soil (pH 7.4) containing moderate organic matter (2.6%). The maximum temperature during the crop growth period ranged from 24.22˚C to 39.48˚C and the minimum temperature varied from 12.89˚C to 28.09˚C. The total rainfall of 1405.87mm was recorded during the crop growth period (NASA-Power, 2018). The daily weather data records from June to November were collected using the database of NASA POWER (2018). The experiment was carried out in two-factorial Randomized Complete Block Design (RCBD) with 9 treatments in different farmers' fields as replications. Three transplanting dates at an interval of 10 days viz. 19th June (early), 29th June (mid) and 9th July (late) were the first factor, whereas three rice cultivars; Arise-6444 (hybrid), Sukkha-3 (improved) and Sarju-52 (local) were the second factor.

Nursery beds were prepared at three different dates for each cultivar in the experimental site. The seedlings were transplanted at an age of 22 days for all the three dates; 19th June, 29th June, and 9th July. The standard package of practices was followed to grow rice (Reddy, 2005).

Fertilizers @100:30:30 kg of N: P_2O_5: K_2O, respectively were applied. Whole of phosphorus and potassium and one third of nitrogen was applied as basal dose and remaining nitrogen was applied equally at active tillering stage and at panicle initiation stage, respectively. Manual weeding was done at 30 and 60 days after transplanting. The crop was harvested and threshed manually and yield was computed at 14% moisture content. The ten fixed rice hills from each plot were randomly selected as sample plants. The major phenological stages; days to panicle initiation, booting, heading, flowering, milking and physiological maturity were recorded. The fields were inspected at 2-3 days intervals to record the dates of their occurrence. Yield attributing traits (Effective tillers m^{-2}, length and weight of panicle, filled grains/panicle) were recorded. Harvesting was done in a 6 m^2 as net area of each plot and thousand-grain weight, grain and straw yields were measured, and yields were computed in terms of per hectare. The various agro-meteorological indices: GDD, HUE and PTI were calculated to predict the phenology and yield of rice as per Sreenivas *et al*. (2010).

GDD = $\{(T_{max}+T_{min})/2\} - T_b$ where, T_{max}= Daily maximum temperature (˚C), T_{min}= Daily minimum temperature (˚C) and Tb=Base Temperature=10 ˚C

HUE = Grain yield (kg ha^{-1})/ GDD

PTI = GDD/ Growth Days

The data collected was refined and entered in MS-Excel sheet. The data was analyzed to draw inferences by using statistical software R-Studio Version 4.0. The mean comparison of different parameters was accomplished using DMRT (Duncan's Multiple Range Test).

RESULTS AND DISCUSSION

Effects of cultivars and transplanting dates on crop phenology

The study revealed that the days required to complete the various phenological stages varied considerably in terms of both the cultivars and the transplanting dates (Table 1). Among the three cultivars, Sarju-52 needed the highest number of days to attain panicle initiation, booting, heading and flowering followed by Sukkha-3 and Arise-6444. Similarly, Arise 6444 required the highest number of days to attain the maturity stage followed by Sukkha-3 and Sarju-52, respectively. Early transplanting of rice required the highest number of days for panicle initiation, booting, heading, and flowering followed by mid and late transplanting dates. In contrast, mid transplanting of rice required the least number of days to attain maturity than the late transplanting, while early transplanting required a greater number of days to reach maturity followed by late transplanting. This finding corroborates with the finding of Bhat et al. (2015) who have stated that major disparity in the number of days taken by different rice cultivars to achieve specific phenological stages is attributed to the different genetic composition and duration of the varieties. Sharma et al. (2011) and Chendge et al. (2017) also suggested that early transplanting utilized more days as a comparison to late transplanting to achieve the physiological maturity. Moreover, Zhao et al. (2016) claim that the internal regulation processes operating via carbohydrate content or leaf/cell longevities likely influence rice phenological processes through hormonal mechanisms. Early transplanting, with favorable temperature, and longer sunshine hours, especially at later stages, promoted crop growth compared with the late transplanting of rice (Abid et al., 2015).

Table 1. Effect of cultivars and transplanting dates on the phenology (calendar days) of rice at Mid-western Terai region of Nepal during 2018

Treatments	Days to Panicle Initiation	Days to booting	Days to heading	Days to flowering	Days to maturity
Due to Cultivars					
Sarju-52	71.11[a]	82.55[a]	97.55[a]	103.55[a]	123.11[c]
Sukkha-3	68.55[b]	78.44[b]	93.22[b]	99.33[b]	128.11[b]
Arise-6444	63.55[c]	73.88[c]	88.66[c]	95.22[c]	132.00[a]
LSD (0.05)	2.035***	1.71***	1.643***	1.41***	0.854***
Due to Transplanting dates					
Early	71.22[a]	82.11[a]	96.88[a]	103.33[a]	131.55[a]
Mid	67.22[b]	77.66[b]	92.44[b]	98.55[b]	124.67[c]
Late	64.77[c]	75.11[c]	90.11[c]	96.22[c]	127.00[b]
LSD (0.05)	2.035***	1.71***	1.643***	1.41***	0.854***

*Note: *, ** and *** represent significant at 5%,1% and 0.1% level of significance respectively, ns= Non-significant, Treatment means followed by a common letter(s) within the column are not significantly different among each other based on DMRT at 0.05 level of significance.*

Table 2. Interaction effect of cultivars and transplanting dates on the phenology of rice at Mid-western Terai of Nepal during 2018

Cultivars x Transplanting dates	Days to panicle initiation	Days to booting	Days to heading	Days to flowering	Days to maturity
Sarju-52					
Early	76.00[a]	88.66[a]	103.33[a]	109.00[a]	123.67[f]
Mid	71.66[bc]	82.00[b]	97.00[b]	103.00[c]	125.33[e]
Late	65.66[def]	77.00[c]	92.33[c]	98.66[d]	120.33[g]
Sukkha-3					
Early-transplanting	74.33[ab]	84.00[b]	99.00[a]	105.66[b]	134.67[b]
Mid-transplanting	69.33[cd]	79.00[c]	94.00[c]	100.00[d]	121.67[g]
Late-transplanting	62.00[fg]	72.33[e]	86.66[d]	92.33[f]	128.00[d]
Arise-6444					
Early-transplanting	63.33[efg]	73.66[de]	88.33[d]	95.33[e]	136.33[a]
Mid-transplanting	60.66[g]	72.00[e]	86.33[d]	92.66[f]	127.00[d]
Late-transplanting	66.66[de]	76.00[cd]	91.33[c]	97.66[de]	132.67[c]
LSD (=0.05)	3.525***	2.967***	2.84***	2.45***	1.479***
CV (%)	3	2.19	1.76	1.42	0.669

, ** and * represent significant at 5%,1% and 0.1% level of significance respectively, ns= Non-significant. Treatment means followed by a common letter(s) within the column are not significantly different among each other based on DMRT at 0.05 level of significance.*

The interaction between cultivars and the transplanting time revealed major variations in the attainment of the specific phenological stages (Table 2). Early transplanted Sarju-52 cultivar required the highest number of days to achieve the various pheno-phases viz. booting and flowering, whereas the early transplanted Sukkha-3 cultivar was statistically close to the early transplanted Sarju-52 for panicle initiation and heading. Arise-6444, transplanted early, needed the maximum number of days to achieve maturity. Similar results were reported by Song *et al.* (1996), Dixit *et al.* (2004) and Linscombe *et al*. (2004), who have reported that early transplanting of rice attains the panicle initiation stage lately. The difference in the maturity time among tested cultivars were due to their genetical varietal characters. The early seeding of rice of all cultivars needing the maximum number of days may be due to sufficient temperature and adequate solar radiation during the growth period (Wani *et al.,* 2016).

Effects of cultivars and transplanting dates on growth parameters, straw yield, and Harvest Index (HI)

The various rice cultivars revealed significant differences for the parameters such as panicle weight, number of tillers, and straw yield, though no major variations were found in Harvest Index (HI). The result showed a substantial variation in the length of the panicle, number of tillers, and HI as affected by the date of transplanting, however, no significant differences was observed in straw yield (Table 3).

Table 3. Effect of cultivars and transplanting dates on the growth parameters, straw yield, and harvest index of rice at Mid-western Terai region of Nepal during 2018

Treatments	Panicle Length	Number of Tillers m^{-2}	Straw Yield (kg ha^{-1})	Harvest Index
Due to Cultivars				
Sarju-52				
	23.47^{c}	231.44^{b}	6244.4^{b}	0.41
Sukkha-3	25.39^{b}	232.11^{b}	6826.6^{b}	0.47
Arise-644	26.72^{a}	250.33^{a}	8860.0^{a}	0.47
LSD (=0.05)	1.186***	15.995*	132**	ns
Due to transplanting date				
Early	25.89^{a}	247.44^{a}	7545.5	0.48^{a}
Mid	24.03^{b}	222.77^{b}	7038.8	0.46^{ab}
Late	25.65^{a}	243.67^{b}	7346.6	0.41^{b}
LSD (=0.05)	1.186**	15.995*	ns	0.053*

, ** and * represent significant at 5%,1% and 0.1% level of significance respectively, ns= Non-significant, Treatment means followed by a common letter(s) within the column are not significantly different among each other based on DMRT at 0.05 level of significance.*

Rice cultivar Arise-6444 produced the longest panicle, highest number of tillers m^{-2}, and highest straw yield. Similar result was also reported by Pandey *et al.* (2001) with a higher number of tillers and higher accumulation of dry matter per plant in a hybrid variety. Both Sarju-52 and Sukkha-3 were statistically similar for the number of tillers and straw yield, while Sukkha-3 was statistically superior over Sarju-52 for panicle length. Under different transplanting times, early transplanted variety was superior regarding panicle length and number of tillers. Dawadi and Chaudhary (2013) also reported longer panicle, HI, and straw yield under early transplanted rice on June 30th which were similar with our results except straw yield. Mid and late transplanted crop showed statistically similar results for the number of tillers. HI of early transplanted rice was statistically at par with mid transplanted ones but superior over late transplanting. The difference in panicle length, tiller number and other parameters amidst the varieties could be due to their varietal characters (Chandrasekhar et al., 2001).

The interaction of different cultivars and transplanting time showed significant differences for panicle length, number of tillers, and HI while non-significant results were obtained for straw yield (Table 4). Early transplanting of Arise-6444 variety showed the highest panicle length which was statistically at par with late transplanting of Sukkha-3. The early transplanting of Sarju-52 was statistically at par with mid and early transplanted Arise-6444, and late transplanted Sukkha-3 for the number of tillers. Early and mid-transplanting of Arise-6444 and Sukkha-3 cultivars as well as the late transplanting of Sarju-52 cultivar were statistically at par for HI. The higher HI of Arise-6444 and Sukkha-3 cultivar could be due to their higher grain yields.

Table 4. Interaction effect of cultivars and transplanting dates on the growth parameters, straw yield, and harvest index of rice at Mid-western Terai region of Nepal during 2018

Cultivars x Transplanting dates	Panicle Length (cm)	Number of Tillers m^{-2}	Straw Yield (kg ha^{-1})	Harvest Index
Sarju-52				
Early	23.46^{de}	272.667^{a}	7856.6	0.39^{b}
Mid	23.13^{e}	194.000^{e}	5976.6	0.41^{b}
Late	23.84^{cde}	227.666^{cd}	4900.0	0.44^{ab}
Sukkha-3				
Early	25.55^{bcd}	223.667^{cd}	6466.6	0.53^{a}
Mid	23.47^{de}	207.667^{de}	6356.6	0.48^{ab}
Late	27.15^{ab}	265.000^{ab}	7656.6	0.38^{b}
Arise-6444				
Early	28.67^{a}	246.000^{abc}	8313.3	0.53^{a}
Mid	25.50^{bcd}	266.666^{ab}	8783.3	0.48^{ab}
Late	25.98^{bc}	238.333^{bc}	9483.3	0.39^{b}
LSD (0.05)	2.05*	27.70***	ns	0.091*
CV (%)	4.71	6.72	18.06	11.69

, ** and * represent significant at 5%,1%, and 0.1% level of significance respectively, ns= Non-significant; Treatment means followed by a common letter(s) within the column are not significantly different among each other based on DMRT at 0.05 level of significance.*

Effects of cultivars and transplanting dates on yield and yield attributing traits

The result showed that there was a significant difference among the cultivars in yield and yield attributing characters except test weight. Early transplanted rice showed a higher weight of panicle, effective tillers m^{-2}, and test weight which were at par with late transplanting (Table 5). It was also observed that Arise-6444 exhibited the highest weight of panicle, effective tillers m^{-2}, grain yield, and grains panicle^{-1} followed by both Sarju-52 and Sukkha-3 cultivar, which were at par for these characters. The sterility percentage was highest in Sukkha-3 along with Arise-6444, whereas Sarju-52 showed lower sterility percentage.

Early transplanting of rice showed the highest weight of panicle, effective tillers m^{-2} and test weight. Similar results were reported by Abhilash et al. (2017). Khalifa (2009) also reported the similar results showing early date of transplanting is the best time of transplanting to gain important yield attributing characters. A large number of productive tillers in early transplanting may be attributed to favorable environmental factors that may have provided optimum weather for enhanced plant growth and production relative to other transplanting dates, the contrasting results were also reported by Soomro et al. (2001). The interaction of cultivars and dates of transplanting showed significant results for effective tillers m^{-2}, grain yield, grains panicle^{-1}, and test weight whereas non-significant results were observed for weight of panicle and sterility percentage (Table 6)..

Table 5. Effect of cultivars and transplanting dates on the yield attributes and grain yield of rice at Mid-western Terai region of Nepal during 2018

Treatments	Weight of panicle	Effective tillers m^{-2}	Grain Yield (kg ha^{-1})	Grains panicle^{-1}	Test Weight(g)	Sterility %
Cultivars						
Sarju-52	3.76^{b}	221.67^{b}	6828.8^{b}	149.42^{b}	25.47	8.74^{b}
Sukkha-3	3.38^{b}	214.44^{b}	6113.3^{b}	166.77^{b}	24.10	15.42^{a}
Arise-6444	4.84^{a}	242.11^{a}	9213.3^{a}	201.64^{a}	25.02	13.30^{ab}
LSD (0.05)	0.599***	15.333**	159.62**	17.75***	ns	4.77*
Transplanting date						
Early	4.376^{a}	233.22^{a}	8042.2	182.31	25.69^{a}	11.72
Mid	3.535^{b}	213.44^{b}	7464.4	173.68	24.63^{ab}	13.06
Late	4.087^{ab}	231.55^{a}	6648.8	161.84	24.26^{b}	12.68
LSD (0.05)	0.599*	15.33*	ns	ns	1.11*	ns

, ** and * represent significant at 5%,1% and 0.1% level of significance respectively, ns= Non-significant, Treatment means followed by a common letter(s) within the column are not significantly different among each other based on DMRT at 0.05 level of significance.*

Early transplanting of Sarju-52 and Arise-6444, late transplanting of Sukkha-3 and Arise-6444 and mid transplanting of Arise-6444 were statistically at par with each other for effective tillers m^{-2} and grain yield. The highest number of grains panicle^{-1} was recorded in Arise-6444 with both early and late transplanting. Early transplanting of Sarju-52, Sukkha-3 and Arise-6444, mid transplanting of Sukkha-3 and Arise-6444 varieties, and late transplanting of Sarju-52 were statistically similar with each other for the test weight. Bashir *et al.* (2010) reported the similar result being the maximum number of effective tillers m^{-2}, the maximum number of grains panicle^{-1}, higher test weight, and higher grain yield when crops were transplanted on the 20th of June. The higher test weight of the early transplanted rice may be due to conducive environments like temperature, humidity for grain development.

The higher grain yield in early transplanted was attributed by higher yield determining factors favored by increased cumulative mean value of temperature and sunshine hour while the decrease grain yield with delayed transplanting could be attributed to the lower number of effective tillers m^{-2}, low test weight, increased sterility percentage, lower weight of panicle and lower grains panicle^{-1}. Late planting of rice resulted in less dry matter and metabolized less photosynthate as a result of less GDD and helio-thermal units (Amgain, 2011). The lower sterility percentage in early transplanting could be due to the optimum photoperiod available for growth, development, and grain-filling period. The higher sterility percentage of Arise-6444 and Sukkha-3 cultivars could be due to long growth duration (Khatun *et al*., 2020).

Table 6. Interaction effect of cultivars and transplanting dates on the yield attributes and grain yield of rice at Mid-western Terai region of Nepal during 2018

Cultivars x T. date	Weight of panicle (g)	Effective tillers m^{-2}	Grain Yield (kg ha^{-1})	Grains $panicle^{-1}$	Test Weight (g)	Sterility %
Sarju-52						
Early	3.747	261.00^{a}	7970.0^{abc}	137.00^{e}	26.04^{a}	6.89
Mid	3.564	188.00^{d}	6580.0^{bcd}	162.40^{cde}	23.81^{bc}	8.68
Late	3.971	216.00^{cd}	5936.6^{cd}	148.66^{de}	26.56^{a}	10.66
Sukkha-3						
Early	3.535	200.66^{d}	4306.6^{d}	157.73^{de}	24.93^{ab}	16.53
Mid	3.116	195.00^{d}	4273.3^{d}	151.53^{de}	25.03^{ab}	17.55
Late	3.512	247.66^{ab}	9760.0^{a}	191.06^{bc}	22.34^{c}	12.20
Arise-6444						
Early	5.845	238.00^{abc}	$1,0116.6^{a}$	226.33^{a}	26.10^{a}	11.76
Mid	3.925	257.33^{ab}	9093.3^{ab}	171.60^{cd}	25.06^{ab}	12.95
Late	4.778	231.00^{bc}	8430.0^{abc}	207.00^{ab}	23.89^{bc}	15.19
LSD (0.05)	ns	26.55***	276.47**	30.74*	1.93**	ns
CV (%)	15.00	6.78	21.62	10.29	4.49	8.21

, ** and * represent significant at 5%,1%, and 0.1% level of significance respectively, ns= Non-significant; Treatment means followed by a common letter(s) within the column are not significantly different among each other based on DMRT at 0.05 level of significance.*

Effect of cultivars and transplanting dates on agro-climatic indices

The effect of transplanting date on cultivars for their agro-climatic indices were found significant. However, non-significant findings were demonstrated for Heat Use Efficiency (HUE) in comparison to specific transplanting dates (Table 7).

Table 7. Effect of cultivars and transplanting date on different climatic indices of rice at Mid-western Terai region of Nepal during 2018

Treatments	GDD	PTI	HUE
<u>Due to cultivars</u>			
Sarju-52	2065.609^{a}	15.90^{a}	3.293^{b}
Sukkha-3	2022.621^{b}	15.77^{b}	3.106^{b}
Arise-6444	1957.303^{c}	15.63^{c}	4.702^{a}
LSD (0.05)	10.14***	0.027***	0.809**
<u>Due to transplanting date</u>			
Early	2150.764^{a}	16.356^{a}	4.25
Mid	1995.628^{b}	15.719^{b}	3.50
Late	1899.141^{c}	15.235^{c}	3.36
LSD (0.05)	10.14 ***	0.027***	ns

, ** and * represent significant at 5%,1% and 0.1% level of significance respectively, ns= Non-significant, GDD=Growing Degree Days, PTI= Pheno Thermal Index and HUE= Heat Use Efficiency; Treatment means followed by a common letter(s) within the column are not significantly different among each other based on DMRT at 0.05 level of significance.*

In case of Sarju-52, the cumulative GDD and PTI were recorded as highest while Arise-6444 displayed the lowest HUE. The early transplanting of the cultivars showed the highest GDD and PTI as regarding the time of transplanting. Significant interactions were found among the times of transplanting and cultivars for all the agro-climatic indices (Table 8). Early transplanting of Sarju-52 showed the highest GDD while the highest PTI was recorded in the case of early transplanting of Arise-6444. Early, mid, and late transplanting of Arise-6444 and late transplanting of Sukkha-3 were statistically similar to each other for HUE. Similar results were noted from the study by Amgain (2011), Abhilash et al. (2017), and Priyadarshi et al. (2018). In the case of late transplanting, the shorter growing degree days and poor heat-use efficiency may be due to a shorter growth period from transplanting to harvest. Arise-6444 showing the highest HUE could be due its genetic factor, and time of transplanting.

Table 8. Interaction effect of cultivars and transplanting dates on different climatic indices of rice at Mid-western Terai region of Nepal during 2018

Cultivars x Transplanting dates	GDD	PTI	HUE
Sarju-52			
Early	2210.995[a]	16.217[b]	3.60[bcd]
Mid	2061.563[c]	15.539[e]	3.19[cde]
Late	1924.270[e]	15.151[h]	3.085[cde]
Sukkha-3			
Early	2189.018[b]	16.255[b]	1.966[e]
Mid	2011.900[d]	15.717[d]	2.124[de]
Late	1866.945[f]	15.345[f]	5.227[a]
Arise-6444			
Early	2052.280[c]	16.595[a]	4.928[ab]
Mid	1913.422[e]	15.539[d]	4.753[ab]
Late	1906.207[e]	15.209[h]	4.423[abc]
LSD (0.05)	17.57 ***	0.047***	1.402**
CV (%)	0.50	0.173	21

, ** and * represent significant at 5%,1% and 0.1% level of significance respectively, ns= Non-significant, GDD=Growing Degree Days, PTI= Pheno Thermal Index and HUE= Heat Use Efficiency; Treatment means followed by a common letter(s) within the column are not significantly different among each other based on DMRT at 0.05 level of significance.*

CONCLUSION

The current study was aimed at assessing the effect of different cultivars and their staggered transplanting on the pheno-phases, yield attributes, yield as well as the agro-climatic indices of rice. The results revealed that cultivar Arise-6444 performed well in terms of most of the yield attributes and grain yield along with a greater HUE. Similarly, the early transplanting of rice resulted in relatively higher yield, yield attributes as well as a greater value of agro-climatic indices. Thus, it can be suggested to rice growers of Lamahi, Dang and rice growers of similar agro-climatic conditions to use Arise-6444 and prefer early transplanting of rice. The varieties having high HUE should be planted early for better yield and to cope with the adverse effect of climate change.

ACKNOWLEDGEMENT

The authors would like to acknowledge Prithu Technical College for providing a wonderful opportunity to carry out this experiment as a part of the Undergraduate Practicum Assessment. Nevertheless, we would like to thank the rice growers of Lamahi, Dang who provided us chance to carry our experiment in their fields. We are also thankful to all the helping hands who supported us throughout the research period.

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