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Growth and yield of rice as affected by transplanting dates and seedlings per hill under high temperature of Dera Ismail Khan, Pakistan

BALOCH Mohammad Safdar[†1], AWAN Inayat Ullah[2], HASSAN Gul[3]
([1]Agricultural Research Institute, Dera Ismail Khan 29050, NWFP, Pakistan)
([2]Department of Agronomy, Faculty of Agriculture, Gomal University, Dera Ismail Khan 29050, NWFP, Pakistan)
([3]Department of Weed Science, NWFP Agricultural University, Peshawar 25130, NWFP, Pakistan)
[†]E-mail: safdarbalochpk@yahoo.com
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Abstract: Studies were initiated for two consecutive years to find out the effect of time of transplanting and seedlings hill^{-1} on the productivity of rice in Dera Ismail Khan district of North West Frontier Province (NWFP), Pakistan. The experiment was laid out in a randomized complete block design with split plot arrangements. Main plots consisted of four transplanting dates viz. 20th and 27th of June and 4th and 11th of July while sub-plots contained 1, 2, 3 or 4 seedlings hill^{-1}. Among transplanting dates, June 20th planted crop gave highest paddy yield and net return with 1 seedling hill^{-1}. It explains that the use of more seedlings hill^{-1} not only adds to cost but is also a mere wastage of natural resources. Based on research findings, we conclude that the use of 1 seedling hill^{-1} is most appropriate for timely sowing otherwise 4 seedlings hill^{-1} should be used to compensate for the yield gap in late transplanted rice.

Key words: Rice, Transplanting time, Seedlings, Yield, Leaf area index, Net assimilation rate
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INTRODUCTION

Rice (*Oryza sativa* L.) production constitutes the major economic activity and a key source of employment for the rural population of Pakistan. The average yield of rice in Pakistan has been increased as a result of many research activities by more than 2% per year but still far less than other leading rice growing countries (Ito *et al*., 1989). Among the crop production tools, proper time and method of sowing are the prerequisites that allow the crop to complete its life phase timely and successfully under a specific agro-ecology. In rice, the optimum leaf areas for seedlings, optimum leaf shapes to maximize photosynthetic efficiency, deep, well-developed root systems, leaf area index (LAI) at flowering and crop growth rate (CGR) during panicle initiation have been identified as the major determinants of yield (Sun *et al*., 1999). A combination of these growth variables explains variations in yield better than any individual growth variable (Ghosh and Singh, 1998). Similarly, Thakur and Patel (1998) reported that dry matter production, leaf area index, leaf area duration (LAD), crop growth rate, net assimilation rate (NAR) and relative growth rate (RGR) are ultimately reflected in higher grain yield of rice. Lu *et al*.(1999) obtained higher yield of rice due to higher net assimilation rate and better distribution of leaf area index after heading.

For successful rice production, timely planting, appropriate control of vegetative growth throughout the duration of the crop, suitable transplanting densities for optimum tillering and control of leaf growth by controlling water, fertilizer and chemical inputs are essential for improving the growth variables responsible for high yield (Ghosh and Singh, 1998).

In Pakistan, rice is transplanted from mid April to end of June depending upon the variety, availability of water, land and labour for rice cultivation in the hot and dry climate of Punjab and Sindh provinces to temperate valley of Swat in NWFP (Khan and Akhter, 2001). In Dera Ismail Khan district of NWFP, the flow of water in irrigation canals remains below its capacity during peak summer season and most growers (70%) have to irrigate their paddy fields at 4~8 d interval (Baloch *et al*., 2004). Therefore, most of the growers start sowing rice nursery from the first fortnight of April. Transplanting is usually completed in the second fortnight of May mainly to avoid the water shortage in hot months of June to July. The April sown rice nurseries mostly escape from the pests' attack thereby reducing the additional cost of inputs in terms of pesticide application. One of the main disadvantages in early transplanted crop is the initiation of sterility (Hassan *et al*., 2003) induced by high temperature resulting in low quality rice from the milling point of view.

The present studies were therefore aimed at determining the effect of transplanting dates and number of seedlings hill^{-1} on the productivity of transplanted rice under the high temperature of Dera Ismail Khan.

MATERIALS AND METHODS

The trials were conducted at the Agricultural Research Institute, Dera Ismail Khan, NWFP, Pakistan, during 2002 and 2003. Dera Ismail Khan (31°49′ N to 70°55′ E) is the extreme southern district of the North West Frontier Province (NWFP) of Pakistan. It is hot and dry in summer with moderate spells during the monsoon season. The elevation ranges from 121 to 210 m above sea level. The mean maximum temperature in summer and winter is 45 °C and 8 °C, respectively. The experiments were carried out in fields where previous crop was wheat during 2002 and chickpea during 2003. The soil was silty clay with pH of 8.3 and organic matter content of <1%. The physio-chemical properties of the experimental area and the meteorological data are shown in Tables 1~2. The morning relative humidity during the rice growing seasons varied from 60% to 69% and 71% to 79% during 2002 and 2003, respectively (Table 2).

The experimental design was a randomized complete block with split plot arrangements, replicated 4 times. The nursery transplanting dates were maintained in the main plots while the number of seedlings hill^{-1} were kept in 2 m×5 m sub-plots with plant-to-plant and row-to-row spacing of 20 cm in each plot. One-month-old nursery of well adapted high yielding coarse rice variety IR-6 was transplanted on 20th and 27th June and 4th and 11th of

Table 1 Physio-chemical characteristics of soils used for experimentation*

Symbol	Unit	Values	
		2002	2003
Previous crop	−	Wheat	Chickpea
Textural class	−	Silty clay	Silty clay
pH (1:5)	1~14	8.3	8.3
Ec ($\times10^6$)	Mmhos	250	250
Ca^{2+}+Mg^{2+}	Meq/L	2.2	3.1
HCO_3	Meq/L	1.8	1.4
Cl	Meq/L	1.3	1.7
Organic matter	%	0.62	0.96
N	%	0.03	0.05
P	10^{-6}	7.0	7.0

* Source: Soil Chemistry Laboratory, Agricultural Research Institute, Dera Ismail Khan, Pakistan

Table 2 Meteorological data recorded during the rice-growing seasons*

Month	2002					2003				
	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	Temperature (°C)		Relative humidity (%)		Rainfall (mm)
	Max	Min	8:00 a.m.	14:00 p.m.		Max	Min	8:00 a.m.	14:00 p.m.	
May	42	24	69	35	29	39	22	71	42	3
June	42	27	60	34	10	42	26	63	34	1
July	40	27	66	37	–	38	27	75	46	60
Aug.	39	27	67	38	5	37	26	78	57	102
Sept.	34	22	64	37	21	35	24	79	57	16
Oct.	32	17	63	40	11	33	33	76	48	–

* Source: Arid Zone Research Institute, Dera Ismail Khan, Pakistan

July each year. Fertilizers were applied at 120, 90, 50 kg/ha of N, P_2O_5 and K_2O, respectively in the form of urea, di-ammonium phosphate and potassium sulphate. Half of N and all P_2O_5 and K_2O were applied at the time of transplantation, while the second half of N was applied at panicle initiation stage. Zinc sulphate (35% Zn) at 12 kg/ha was applied 15 d after transplanting. Data were recorded on agronomic parameters including number of productive tillers m^{-2}, spikelets panicle^{-1}, 1000-grain weight (g), paddy yield (t/ha) and physiological characteristics like leaf area index (LAI) and net assimilation rate (NAR) 45 and 90 d after transplanting (DAT). The data were analyzed statistically using analysis of variance technique and significant means were separated using least significance difference test (LSD) for comparing the treatment means (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

Number of productive tillers (m^{-2})

Among yield components, productive tillers are very important because the final yield is mainly a function of the number of panicles bearing tillers per unit area. The data presented in Table 3 indicated that the transplanting dates differed significantly during 2002. The plots transplanted on 4th of July produced significantly higher productive tillers (506.6 m^{-2}), followed by 20th of June with 462.4 productive tillers m^{-2}. The lowest number of tillers (397.9 m^{-2}) was recorded on 11th of July during 2002. Although non-significant statistically, the crop planted on 27th of June produced the highest number of productive tillers (486.8 m^{-2}), followed by 20th of June with 456.1 tillers m^{-2} during 2003. Hassan *et al*.(2003) noted the highest number of tillers in their similar studies in the crop planted in June under Dera Ismail Khan conditions. As regards effect of seedlings hill^{-1}, the maximum tillers were noted (461.5 and 495.0 m^{-2}) with 4 seedlings hill^{-1} during both experimental years, though the difference was significant only in the second year trial. The interaction between transplanting dates and seedlings hill^{-1} was found significant during both cropping seasons. The maximum tillers (548.3 m^{-2}) were recorded on 4th of July with 4 seedlings hill^{-1} followed by 533.3 productive tillers m^{-2} with 3 seedlings hill^{-1} on the same date during 2002. In 2003, July 4th planted crop again produced significantly maximum number of productive tillers (604.3 m^{-2}) with 4 seedlings hill^{-1} followed by 27th and 20th June crop, which produced 557 and 550 tillers m^{-2} with 1 seedling hill^{-1}. The higher number of productive tillers during 2003 might be due to comparatively lower temperature, higher rainfall, humidity and organic matter than the preceding year (Tables 1~2). Ashraf *et al*.(1999) stated that transplanting of 2 and 3 seedlings hill^{-1} of 35 d old nursery gave more promising results in terms of more productive tillers per unit area. While, Zhong *et al*.(2001) found that the productive tiller percentage was significantly and negatively correlated with maximum tiller number per unit area.

Number of spikelets panicle^{-1}

Data given in Table 4 show that the crop planted on 27th of June gave the highest number of spikelets panicle^{-1} (171.1) during 2002. Likewise, significantly the maximum spikelets panicle^{-1} (205.6) were recorded on the same planting date followed by 11th of

Table 3 Number of productive tillers (m^{-2}) as affected by time of transplanting and seedlings hill^{-1} in transplanted rice during 2002 and 2003

Seedlings hill^{-1}	2002					2003				
	Date of transplanting				Means	Date of transplanting				Means
	June 20	June 27	July 4	July 11		June 20	June 27	July 4	July 11	
1	511.5abc	470.0a~d	438.3a~d	365.0d	446.1^{NS}	550.0b	557.0b	357.3hi	394.3gh	464.6b
2	463.3a~d	450.0a~d	506.5abc	380.0d	449.9	392.3gh	482.0c	345.3i	348.5i	392.0d
3	426.5a~d	391.5cd	533.3ab	413.3bcd	441.1	400.3fg	438.3def	448.5cde	423.5efg	427.6c
4	448.3a~d	416.5bcd	548.3a	433.3a~d	461.5	482.3c	470.0cd	604.3a	423.5efg	495.0a
Means	462.4b	432.0bc	506.6a	397.9c		456.1^{NS}	486.8	438.8	397.4	

$LSD_{0.05}$ (transplanting dates) 2002=37.61; $LSD_{0.05}$ (seedlings hill^{-1}) 2003=20.02; $LSD_{0.05}$ (transplanting dates×seedlings hill^{-1}) 2002=123.4; $LSD_{0.05}$ (transplanting dates×seedlings hill^{-1}) 2003=40.03; Means followed by different letter(s) are significant at 5% level of probability using *LSD* test; ^{NS}: Non-significant

July with 184.9 number of spikelets panicle^{-1} in 2003. Seedlings hill^{-1} differed significantly during both the experimental years and plots sown with 4 seedlings hill^{-1} produced the maximum spikelets panicle^{-1} (168.2 and 203.5) though at par statistically with 1 seedling hill^{-1} (164.4 and 193.3 panicle^{-1}). The interaction between transplanting dates and seedlings hill^{-1} was found significant during both cropping seasons. The 27th June crop with 2 seedlings hill^{-1} in 2002 and 1 seedling hill^{-1} in 2003 gave higher number of spikelets panicle^{-1} (184.5 and 236.5). While minimum number of spikelets panicle^{-1} (133.8 and 142.3) were recorded on 11th of July with 3 seedlings hill^{-1} and 4th of July with 1 seedling hill^{-1} during 2002 and 2003, respectively. Many factors affect the spikelets panicle^{-1} such as genotype, cultural practices used (planting date, seeding rate and soil fertility) and growing conditions (air and soil temperature, etc.). The spikelets panicle^{-1} were increased substantially either with 1 or 4 seedlings hill^{-1} during both the years, explaining that use of single seedling has the potential to produce as much spikelets as 4 seedlings hill^{-1}. Similar effects of seedlings were also noted on number of productive tillers per unit area probably because planting 1 seedling resulted in higher growth rate, which eventually increased healthy seedlings.

1000-grain weight (g)

Thousand-grain weight, an important yield-determining component, is a genetic character least influenced by environment (Ashraf *et al*., 1999). Table 5 data revealed that during 2002 the grain weight was significantly higher (24.6 and 24.5 g) on 20th and 27th of June than the July planted crop. Similarly, the crop planted on 20th June produced heavier grains followed by 27th of June and 11th of July during 2003. Transplanting date 4th of July produced lower grain weight (23.6 and 28.1 g) during both the experimental years. Data on the effect of seedlings hill^{-1} showed significantly higher grain weight (24.5 g) in plots sown with 4 seedlings hill^{-1} followed by 1 seedling hill^{-1} (24.3 g) during 2002. Whereas, crop planted with 1 seedling hill^{-1} gave heavier grains (29.3 g) followed by 4 seedlings hill^{-1} (28.8 g) during the second planting season. The

Table 4 Number of spikelets panicle^{-1} as affected by time of transplanting and seedlings hill^{-1} in transplanted rice during 2002 and 2003

Seedlings hill^{-1}	2002					2003				
	Date of transplanting				Means	Date of transplanting				Means
	June 20	June 27	July 4	July 11		June 20	June 27	July 4	July 11	
1	176.5abc	184.0ab	142.0ef	155.3c~f	164.4a	209.5bc	236.5a	142.3i	185.0def	193.3a
2	161.0b~e	184.5a	147.5def	146.5def	159.9ab	152.3hi	192.5cde	156.5ghi	164.0f~i	166.3b
3	164.3a~e	152.0def	160.3cde	133.8f	152.6b	173.0e~h	189.0cde	180.5d~g	164.5f~i	176.8b
4	164.3a~e	164.0a~e	168.5a~d	176.0abc	168.2a	188.0c~f	204.5bcd	195.3cde	226.3ab	203.5a
Means	166.5^{NS}	171.1	154.5	152.8		180.7bc	205.6a	168.6c	184.9b	

$LSD_{0.05}$ (seedlings hill^{-1}) 2002=11.72; $LSD_{0.05}$ (transplanting dates) 2003=15.87; $LSD_{0.05}$ (transplanting dates×seedlings hill^{-1}) 2002=23.44; $LSD_{0.05}$ (seedlings hill^{-1}) 2003=12.06; $LSD_{0.05}$ (transplanting dates×seedlings hill^{-1}) 2003=24.11; Means followed by different letter(s) are significant at 5% level of probability using *LSD* test; ^{NS}: Non-significant

Table 5 1000-grain weight (g) as affected by time of transplanting and seedlings hill^{-1} in transplanted rice during 2002 and 2003

Seedlings hill^{-1}	2002					2003				
	Date of transplanting				Means	Date of transplanting				Means
	June 20	June 27	July 4	July 11		June 20	June 27	July 4	July 11	
1	25.0a	24.9ab	23.8c~f	23.6def	24.3ab	30.0ab	30.4a	27.9efg	29.2a~e	29.3a
2	24.9ab	24.8ab	23.1f	23.5def	24.1bc	28.5c~f	28.7b~f	28.3d~g	28.3d~g	28.4b
3	24.0cde	23.9cde	23.4ef	24.2bcd	23.9c	29.4a~d	28.4c~f	27.0g	28.1d~g	28.2b
4	24.5abc	24.6abc	23.9cde	25.2a	24.5a	28.7b~f	27.8fg	29.2a~f	29.8abc	28.8ab
Means	24.6a	24.5a	23.6c	24.1b		29.1^{NS}	28.8	28.1	28.8	

$LSD_{0.05}$ (transplanting dates) 2002=0.35; $LSD_{0.05}$ (seedlings hill^{-1}) 2002=0.37; $LSD_{0.05}$ (seedlings hill^{-1}) 2003=0.70; $LSD_{0.05}$ (transplanting dates×seedlings hill^{-1}) 2002=0.75; $LSD_{0.05}$ (transplanting dates×seedlings hill^{-1}) 2003=1.41; Means followed by different letter(s) are significant at 5% level of probability using *LSD* test; ^{NS}: Non-significant number of seedlings hill^{-1} was significantly affected during both the years. The 20th June crop during 2002 and 27th of June during 2003 produced the highest grain weight (25.0 and 30.4 g) both with 1 seedling hill^{-1}, although the means were significant only during 2002. Transplanting date 4th of July which showed the highest number of productive tillers m^{-2} (506.6) resulted in lower grain weight (23.1 and 27.0 g) with 2 and 3 seedlings hill^{-1} coinciding with the observation that higher number of tillers reduces the number, size and weight of grains (Lockhart and Wiseman, 1988). Our findings also accord with those of Wen and Yang (1991) who reported higher 1000-grain weight by using 1 seedling hill^{-1} than with 4 seedlings hill^{-1}. Similarly, Singh (1994) noted that the number of grains and grain weight panicle^{-1} were positively correlated with grain yield. The higher 1000-grain weight during 2003 might be due to supply of sufficient amount of organic matter and/or slow release of nitrogen available at all the kernel development stages.

Paddy yield (t/ha)

Grain yield is a function of interplay of various yield components such as number of productive tillers, spikelets per panicle and 1000-grain weight (Hassan *et al*., 2003). Among planting dates, maximum paddy yield (4.5 t/ha) was produced on 20th June and 11th of July while the rest of two transplanting dates (27th of June and 4th of July) produced comparatively lower paddy yield each of 4.1 t/ha during 2002 (Table 6). The planting date 20th of June produced the highest yield of 5.0 and 8.1 t/ha with 1 seedling hill^{-1} during both planting seasons, though the interaction between transplanting dates and seedlings hill^{-1} was significant only in 2002. It was, however, statistically at par with 11th of July which gave 4.9 t/ha paddy yield with 3 and 4 seedlings hill^{-1} in the same year. The highest paddy yield on 20th of June might have been due to maximum number of productive tillers m^{-2}, spikelets panicle^{-1} and 1000-grain weight. Moreover, the higher production with 1 seedling hill^{-1} explained that single seedling consumed more nutrients than 2, 3 and 4 seedlings. It also took advantage of low vegetative biomass in the initial growth stages. Similar findings were reported by Wen and Yang (1991) who obtained higher rice yield, effective panicles, number of grains panicle^{-1} and 1000-grain weight by planting 1 seedling hill^{-1}. Likewise, Srinivasulu *et al*.(1999) noted that planting 1 seedling hill^{-1} of rice gave grain yield comparable to that of 2 seedlings hill^{-1}. Among planting dates, Hassan *et al*.(2003) also obtained higher paddy yield of IR-6 on 25th of June as compared to 5th and 15th of July in Dera Ismail Khan. Pal *et al*.(1999) also reported higher paddy yield when transplanted on 15th or 29th of June. The increased productivity of rice might be due to better physical, chemical and biological characteristics of soil on account of previous chickpea crop, increased N utilization efficiency, higher organic matter and/or better ecological conditions during 2003 that caused a parallel increase in the respective yielding components (Tables 1~2).

Leaf area index (m^{-2}) 45 DAT

Leaf area index is the efficiency of photosynthetic process and on the extent of photosynthetic surface (Lockhart and Wiseman, 1988). Data revealed non-significant differences among various planting dates for two cropping seasons (Table 7). Plots transplanted on 27th of June and 11th of July showed numerically increased LAI (9.0 and 12.44 m^{-2}) during

Table 6 Paddy yield (t/ha) as affected by time of transplanting and seedlings hill^{-1} in transplanted rice during 2002 and 2003

Seedlings hill^{-1}	2002					2003				
	Date of transplanting				Means	Date of transplanting				Means
	June 20	June 27	July 4	July 11		June 20	June 27	July 4	July 11	
1	5.0a	4.6ab	4.0bc	4.1bc	4.4^{NS}	8.1^{NS}	5.5	5.7	5.5	6.2^{NS}
2	4.6ab	4.1bc	4.0bc	4.4abc	4.3	5.9	5.6	6.7	5.5	5.9
3	4.2bc	3.9c	4.2bc	4.9a	4.3	6.5	4.7	6.1	6.5	5.9
4	4.2bc	4.0bc	4.2bc	4.9a	4.3	7.3	4.8	7.9	6.9	6.7
Means	4.5^{NS}	4.1	4.1	4.5		6.9^{NS}	5.1	6.6	6.1	

$LSD_{0.05}$ (transplanting dates×seedlings hill^{-1}) 2002=0.64; Means followed by different letter(s) are significant at 5% level of probability using *LSD* test; ^{NS}: Non-significant

2002 and 2003, respectively. It was also noted that LAI increased significantly by using 1 seedling hill^{-1} (9.07 m^{-2}) followed by 4 seedlings hill^{-1} (8.82 m^{-2}) during 2002. The interaction between transplanting dates and number of seedlings hill^{-1} significantly increased LAI (11.19 m^{-2}) on 27th June planted crop, followed by 20th of June (10.24 m^{-2}) with 1 seedling hill^{-1} in 2002. Relatively higher LAI on 20th of June and 11th of July planted crops ultimately contributed towards higher paddy yield and its contributing components during both planting seasons. The higher LAI during 2003 could be attributed to biological variability between the years (Tables 1~2) that resulted in a different leaf shape (length, width) and possibly number of leaves plant^{-1}. Singh (1994) observed a positive correlation between LAI and NAR towards higher paddy yield at all phenological stages. While Zhong *et al*.(2002) stated that transplanting, spacing and number of seedlings hill^{-1} had little effect on LAI. Such variations in results might be due to change in environmental conditions and/or genetic make-up of the germplasm.

Leaf area index (m^{-2}) 90 DAT

The complex growth of crops might be simplified by considering two growth components in a plant community, the LAI and NAR. Data shown in Table 8 depicted numerically higher LAI on 20th and 27th of June (13.27 m^{-2}) during 2002 while transplanting date 11th and 4th of July exhibited increased LAI of 13.38 and 12.33 m^{-2}, respectively in 2003. Similarly, the crop sown with 1 seedling hill^{-1} gave maximum LAI of 14.97 m^{-2} followed by 4 seedlings hill^{-1} (14.58 m^{-2}) during 2002. In the second cropping season, the seedlings hill^{-1} inversely affected LAI where the use of 4 seedlings hill^{-1} showed maximum LAI compared to 1 seedling hill^{-1}. The interaction between transplanting dates and seedlings hill^{-1} was found significant during both cropping seasons. It was noted that the crop planted on 20th June produced the highest LAI (17.17 m^{-2}) with 1 seedling hill^{-1}, though at par statistically with 27th of June during 2002. Similarly, transplanting date 11th July had significantly more LAI (15.45 m^{-2}), followed by 4th July (15.34 m^{-2}) both with 4 seedlings hill^{-1} in 2003. Our findings accord with those of Ghosh and Singh (1998) who observed a strong and positive correlation of LAI with grain yield. They stated that LAI at flowering showed yield variation of 79% and delay in planting by 15 d drastically affected LAI of rice. Other

Table 7 Leaf area index (m^{-2}) as affected by time of transplanting and seedlings hill^{-1} in transplanted rice 45 DAT during 2002 and 2003

Seedlings hill^{-1}	2002					2003				
	Date of transplanting				Means	Date of transplanting				Means
	June 20	June 27	July 4	July 11		June 20	June 27	July 4	July 11	
1	10.24ab	11.19a	7.57efg	7.29efg	9.07a	12.86^{NS}	10.75	10.60	11.40	11.40^{NS}
2	7.91efg	8.06d~g	6.79g	8.79cde	7.87b	10.35	8.38	10.32	10.62	9.92
3	7.18fg	8.32c~f	7.62efg	9.96d~g	7.77b	11.55	9.31	9.39	12.97	10.86
4	7.64efg	8.42c~f	9.43bcd	9.79abc	8.82a	11.56	10.53	9.89	14.78	11.69
Means	8.24^{NS}	9.00	7.85	8.44		11.58^{NS}	9.74	10.05	12.44	

$LSD_{0.05}$ (seedlings hill^{-1}) 2002=0.74; $LSD_{0.05}$ (transplanting dates×seedlings hill^{-1}) 2002=1.49; Means followed by different letter(s) are significant at 5% level of probability using *LSD* test; ^{NS}: Non-significant

Table 8 Leaf area index (m^{-2}) as affected by time of transplanting and seedlings hill^{-1} in transplanted rice 90 DAT during 2002 and 2003

Seedlings hill^{-1}	2002					2003				
	Date of transplanting				Means	Date of transplanting				Means
	June 20	June 27	July 4	July 11		June 20	June 27	July 4	July 11	
1	17.17a	17.17a	11.68d~h	13.47c~g	14.97a	13.05abc	15.28ab	10.64c	11.37c	12.58^{NS}
2	11.32e~h	11.06fgh	10.70gh	8.70h	10.44c	12.70abc	12.39abc	11.89bc	11.58c	12.14
3	11.54e~h	11.39e~h	13.93c~f	11.42e~h	12.07b	11.88bc	9.97c	11.44c	12.28abc	11.39
4	13.06c~g	14.36b~e	14.71a~d	16.19abc	14.58a	11.38c	11.34c	15.34ab	15.45a	13.38
Means	13.27^{NS}	13.27	12.76	12.45		12.25^{NS}	12.24	12.33	13.38	

$LSD_{0.05}$ (seedlings hill^{-1}) 2002=1.57; $LSD_{0.05}$ (transplanting dates×seedlings hill^{-1}) 2002=3.14; $LSD_{0.05}$ (transplanting dates×seedlings hill^{-1}) 2003=3.54; Means followed by different letter(s) are significant at 5% level of probability using *LSD* test; ^{NS}: Non-significant researchers like Hari *et al*.(1999) noted a higher LAI in June than in July transplanted crop. Wada *et al*.(2002) stated that a higher crop growth rate after anthesis mainly due to the high mean LAI during the ripening period. In addition, they noted relatively high NAR despite recording high mean LAI during the ripening period.

Net assimilation rate (g/(m^2·d)) 45 DAT

Net assimilation rate is the physiological potential for converting the total dry matter into grain yield. The NAR is used as a measure of the rate of photosynthesis minus respiration losses (Sun *et al*., 1999). Table 9 data revealed that transplanting date 27th of June produced higher NAR (32.38 g/(m^2·d)) during 2002. Whereas the 20th of June and 11th of July planted crops revealed similar NAR of 29.97 g/(m^2·d) in the same year. In 2003, transplanting date 4th of July produced significantly higher NAR (39.44 g/(m^2·d)) as compared to 20th of June, which showed lower NAR of 26.28 g/(m^2·d). The NAR was influenced significantly by seedlings hill^{-1} during 2002 where the crop planted with 3 seedlings hill^{-1} resulted in higher NAR (32.08 g/(m^2·d)) though at par statistically with 4 seedlings hill^{-1}. Similarly, the significant interaction between transplanting dates and number of seedlings hill^{-1} resulted in the highest NAR (37.07 g/(m^2·d)) on 27th of June with 3 seedlings hill^{-1} during 2002. It was followed by 11th of July (35.01 g/(m^2·d)) with 1 seedling hill^{-1}. Like other growth components, the NAR being also higher during 2003 again is attributed to higher soil fertility status, high rainfall, humidity and organic matter than the previous year (Tables 1~2). The translocation of slow release N might have boosted the vegetative plant growth drastically during 2003.

Net assimilation rate (g/(m^2·d)) 90 DAT

Temperature, light, carbon dioxide, water, leaf age, mineral nutrients, chlorophyll content and genotype influence net assimilation rate (Hari *et al*., 1999). Table 10 data revealed non-significant differences among treatment means during 2002. In the second planting season, the crop planted on 27th of June gave significantly higher NAR (31.64 g/(m^2·d)) compared with 11th of July, which showed a declining

Table 9 Net assimilation rate (g/(m^2·d)) as affected by time of transplanting and seedlings hill^{-1} in transplanted rice 45 DAT during 2002 and 2003

Seedlings hill^{-1}	2002					2003				
	Date of transplanting				Means	Date of transplanting				Means
	June 20	June 27	July 4	July 11		June 20	June 27	July 4	July 11	
1	27.72c~f	31.56a~d	24.94ef	35.01ab	29.81ab	23.69^{NS}	38.46	37.96	29.65	32.44^{NS}
2	24.44f	31.45a~d	27.40def	24.88ef	27.04b	23.79	34.82	43.87	35.68	34.54
3	33.86abc	37.07a	28.92b~f	28.46c~f	32.08a	28.53	39.27	38.78	36.90	35.87
4	31.15a~e	29.45b~f	33.77abc	31.54a~d	31.48a	29.13	37.15	37.13	35.36	34.69
Means	29.97^{NS}	32.38	28.76	29.97		26.28b	37.43a	39.44a	34.40a	

$LSD_{0.05}$ (seedlings hill^{-1}) 2002=3.16; $LSD_{0.05}$ (transplanting dates) 2003=7.17; $LSD_{0.05}$ (transplanting dates×seedlings hill^{-1}) 2002=6.32; Means followed by different letter(s) are significant at 5% level of probability using *LSD* test; ^{NS}: Non-significant

Table 10 Net assimilation rate (g/(m^2·d)) as affected by time of transplanting and seedlings hill^{-1} in transplanted rice 90 DAT during 2002 and 2003

Seedlings hill^{-1}	2002					2003				
	Date of transplanting				Means	Date of transplanting				Means
	June 20	June 27	July 4	July 11		June 20	June 27	July 4	July 11	
1	38.33^{NS}	41.94	38.40	43.70	40.59a	37.07a	36.74a	23.87ef	25.42def	30.77a
2	30.92	34.44	34.62	34.27	33.56c	30.39bcd	29.46b~e	27.29c~f	23.06f	27.55bc
3	28.14	37.78	39.16	36.66	35.44bc	24.93def	26.56c~f	25.17def	24.03ef	25.17c
4	30.00	37.03	39.44	47.40	38.47ab	30.47bcd	33.81ab	31.37abc	25.50def	30.28ab
Means	31.85^{NS}	37.80	37.91	40.51		30.71ab	31.64a	26.92bc	24.50c	

$LSD_{0.05}$ (transplanting dates) 2003=4.34; $LSD_{0.05}$ (seedlings hill^{-1}) 2002=4.03; $LSD_{0.05}$ (seedlings hill^{-1}) 2003=2.90; $LSD_{0.05}$ (transplanting dates×seedlings hill^{-1}) 2003=5.80; Means followed by different letter(s) are significant at 5% level of probability using *LSD* test; ^{NS}: Non-significant trend and lower NAR (24.50 g/(m^2·d)). The data further revealed that significantly higher NAR (40.59 and 30.77 g/(m^2·d)) was obtained by using 1 seedling $hill^{-1}$ during both cropping seasons. It was followed by crop planted with 4 seedlings $hill^{-1}$, which showed NAR of 38.47 and 30.28 g/(m^2·d), respectively. The interaction between transplanting dates and seedlings $hill^{-1}$ was significant in 2003, where the crop planted on 20th June had increased NAR with 1 seedling $hill^{-1}$, though at par statistically with 27th of June in the same year. The higher NAR with 1 seedling $hill^{-1}$ manifested the potential of single seedling to contribute as much as or even more towards higher productivity of rice. Lu *et al*.(2000) observed that decrease in the rate of photosynthesis in leaves cause parallel decrease in NAR and eventually low grain yield. Similarly, Thakur and Patel (1998) stated that NAR is one of the factors responsible for higher paddy yield.

CONCLUSION

In the present research, it is clear that time of transplanting and number of seedlings $hill^{-1}$ influenced most of the growth parameters, considerably. Among transplanting dates, June 20th planted crop gave higher paddy yield with 1 seedling $hill^{-1}$. It indicated that single seedling not only consumed more nutrients than 2, 3 and 4 seedlings but also had the benefit of low vegetative biomass in the initial growth stages. Therefore, transplanting date 20th June with 1 seedling $hill^{-1}$ is recommended for successful rice production under the agroclimatic conditions of the area.

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