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COMPARATIVE EFFECT OF LOCATION, TRANSPLANTING DATE AND TRANSPLANTING DENSITY ON PERFORMANCE OF RICE VARIETY BASMATI-515

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To investigate the combined effect of location, transplanting date and transplanting density on phenology, growth, yield and radiations use efficiency of rice, a 2-year experiment was conducted at 3 locations (Gujranwala, Hafizabad and Faisalabad) in Punjab (Pakistan). Six transplanting dates (10th June, 20th June, 30th June, 10th July, 20th July and 30th July) and three transplanting densities (1, 2 and 3 seedlings per hill) were randomized in main and sub-plots, respectively under Randomized Complete Block Design with split plot arrangement. The results indicated that most of the studied parameters were affected significantly. In case of locations, both years average maximum Paddy yield (3249 kg ha^{-1}), Leaf area index (5.56), Crop growth rate (25.35 g m^{-2} day^{-1}),Paddy yield radiations use efficiency (1.26 g MJ^{-1}) and Biological yield radiations use efficiency (5.23 g MJ^{-1}) were recorded at Gujranwala. Among transplanting dates, average maximum Paddy yield (3688 kg ha^{-1}), Leaf area index (6.05), Crop growth rate (28.94 g m^{-2} day^{-1}),Paddy yield radiations use efficiency (1.38 g MJ^{-1}) and Biological yield radiations use efficiency (5.37 g MJ^{-1}) were recorded in 30th June, 20th June, 20th July, 30th June and 20th July transplanted rice, respectively. In case of transplanting densities, maximum Paddy yield (3186 kg ha^{-1}) and Paddy yield radiations use efficiency (1.25 g MJ^{-1}) were observed in 2 seedlings per hill and maximum Leaf area index (5.88), Crop growth rate (24.11 g m^{-2} day^{-1}) and Biological yield radiations use efficiency (5.14 g MJ^{-1}) were recorded in 3 seedlings per hill transplanted rice.
Keywords: Rice, Transplanting date, Transplanting density, Paddy yield.

INTRODUCTION

Pakistan is the 11th largest producer and 4th largest exporter of rice (*Oryza sativa* L.) in the world (Shahzadi*et al.*, 2018). Together with South Asia, the country is fulfilling 30% of the world's paddy requirements (Calpe, 2005). Punjab, a province of Pakistan is the home of more than 60% country's population where rice followed by wheat is the 2nd major source of economic activity for rural inhabitants. It is also, a fundamental to poverty and food insecurity alleviation (Government of Pakistan, 2019). The province covers 59.46% of the total rice area and produces 91.2% country's fine quality aromatic basmati rice of international demand. Even after having such qualities, basmati rice is not expressing its full yield potential due to indefinite transplanting time and poor plant population per unit area (Sharma *et al.*, 2011). Furthermore, performance of a specific rice variety with respect to optimum transplanting date also differs at location and region levels (Bashir *et al.*, 2010).

Manipulated transplanting of rice affects its performance via exposing it to differential precipitation, temperatures and growth period (Safdar *et al.*, 2013). Proper transplanting time of rice not only ensures enough vegetative growth at ideal temperatures and solar radiations, but also escapes it from drastic low night temperatures that guarantees grain filling at desired time (Akbar *et al.*, 2010) . Too early or late transplanting of rice is one of the major factors of reduced rice yield. Early transplanting enhances sterility, while late transplanting reduces the number of productive tillers (Nishad *et al.*, 2018). Delayed transplanting also causes severe reduction in dry matter accumulation. Tari (2012) affirmed that transplanting date impacted yield contributing factors, such as the number of productive tillers, sterile spikelets per panicle and 1000-grain weight. Moradpour*et al.* (2013) found that transplanting date had considerable impact on development parameters of rice. They led an examination in Iran to explore the impact of three transplanting dates (30th May, 9th June and 20th June) on rice. The results indicated that maximum yield was obtained in 9th June transplanted rice. Ahmad *et al.* (2015) concluded from a comprehensive study that reason of low rice yield at farmer level is wide transplanting span in Pakistan.

Another important factor of low rice yield is the poor plant population (Ahmad *et al.*, 2005; Gorgy, 2010). Optimum plant population is prerequisite for efficient resources utilization e.g. solar radiations, temperatures, moisture and fertilizers (Baloch *et al.*, 2002;Bozorgi*et al.*, 2011; Mohaddesi *et al.*, 2012). Above or below than recommended plant population affects growth and yield due to resources competition at critical growth and development stages

(Ahmad*et al.,* 2009). Plant population above optimum, increases competition among plants for light and nutrients that weakens the plant and ultimately low yield is obtained (Mondal *et al.,* 2013), while plant population below optimum, causes resources wastage. Fukushima *et al.* (2011) researched that 2 seedlings per hill were ideal for getting highest yield of summer rice. Shakeel and Mirza (2012) conducted a trial comprising of three planting densities (1, 2 and 3 seedlings per hill). They got maximum biomass and grain yield at 2 seedlings per hill.

Keeping in view the above factors, it is necessary to determine the optimum transplanting date and number of transplanted seedling per hill at specific location to get economical rice yield (Hossain *et al.,* 2003).Basmati-515 is a newly evolved, stiff stemmed, lodging resistant, extra-long grain and high yielding rice variety developed at Rice Research Institute Kala Shah Kaku, Punjab, Pakistan (Akhtar *et al.,* 2014; Ashfaq *et al.,* 2015). Even after such ideal characters, it is not famous among farming community due to some issues like improper transplanting time and transplanting density. As in Punjab, basmati rice transplanting starts in June and continues till end of July with no consideration to transplanting time and number of transplanted seedlings per unit area. Such a wide transplanting time span of almost 2 months along with poor plant population lays considerable negative impacts on harvested paddy yield. So, a multi-location trial was conducted in core and non-core rice area of Punjab to investigate the effect of different transplanting dates and number of transplanted seedlings per hill on basmati-515 performance.

MATERIALS AND METHODS

The experiment was conducted on newly developed rice variety (Basmati-515) in Kharif seasons (April-October) during 2015 and 2016 at 3 locations (Table 1) in Punjab, Pakistan. Field was prepared by 2-disc harrow followed by 2-cultivation and LASER land leveling. Before transplanting, it was puddled to create a hardpan. Manual transplanting of rice under Randomized Complete Block Design (RCBD) with split-split plot arrangement was done. There were three replications. Randomization of 6 transplanting date (10^{th}June, 20^{th} June, 30^{th} June, 10^{th} July, 20^{th} July and 30^{th} July) in main plots and 3 transplanting density (1, 2 and 3 seedlings per hill) in sub-plots was done through random number technique at each location. Net plot size 7m×1.8m was used. Plant to plant and row to row distance was 22 cm. In each transplanting date 30 days old nursery was transplanted. Zn in the form of $ZnSo_4$ (33%) was broadcasted in nursery at the rate of 75 kg ha^{-1} to overcome its deficiency, a common phenomenon in transplanted rice. Irrigation was applied whenever needed. Recommended dose of nitrogen (150 kg ha^{-1}) in 3 splits (1/3 at transplanting, 1/3 top dressed at tillering and 1/3 top dressed at panicle initiation) in the form of urea, phosphorus (100 kg ha^{-1} before transplanting) in the form of diammonium phosphate (DAP) and potash (75 kg ha^{-1} before transplanting) in the form of sulphate of potash were applied. Manual weeding was done whenever needed. Weather data for each year was collected from the observatory of Pakistan Meteorological Department (PMD)nearest to each location (Table 2). The data were analyzed by following the Fishers analysis of variance technique and means were compared at 5% probability (Steel *et al.,* 1997). The data on different parameters were collected as explained below.

***Phenology*: ** For crop phenology, 6 plants were randomly tagged in each plot and observed on daily basis. The day when the particular event (tillering, anthesis and physiological maturity) in 3 out of 6 tagged plants was observed considered as the time of the event. Days to tillering were considered when a new plant from the mother seedlings became visible. Anthesis day was considered as the day of panicle exertion from flag leaf. Physiological maturity was considered when half of the palea and lemma of kernel reached to yellow ripe stage.

***Leaf area index (LAI) and crop growth rate (CGR*)**:** Three hills from ground level were harvested from each plot at 15 days interval to study the time scale crop growth rate (CGR) and leaf area index (LAI). Fresh and dry weights of component fractions (Leaf, stem and panicle) were determined after counting the number of tillers. A 20-gm whole leaf lamina was used to measure leaf area on leaf area meter (Licor-2000) and converted by unit method. LAI was calculated as the ratio of leaf area to land area (equation-1) (Watson, 1947). A 15-day interval CGR was calculated on the basis of oven dried weight of component fractions as proposed by Hunt (1978) and converted to gm ha^{-1} by unit method (equation-2).

Table 1. Geographical characteristics of selected locations of experimentation.

Location	Latitude N°	Longitude E°	Elevation from sea level	Annual rainfall	Climatic zone
Gujranwala	30°40´	73°06´	172	485.8	Sub-humid (core rice area), Relative humidity 70-75%, (Saifullah and Hassan, 2019)
Hafizabad	32°04´	72°67´	188	307.9	Semi-arid (core rice area), Relative humidity 35-40%, (Saifullah and Hassan, 2019)
Faisalabad	31°26´	73°04´	184	277.6	Semi-arid (non-core rice area)

Table 2. Average weather conditions during both years at selected locations of experimentation

Year	TD	GRW			HFD			FSD		
		Max T (°C)	**Min T (°C)**	**Total rain (mm)**	**Max T (°C)**	**Min T (°C)**	**Total rain (mm)**	**Max T (°C)**	**Min T (°C)**	**Total rain (mm)**
2015	10th June	35.29	24.66	337	35.69	25.81	301	36.28	26.05	311
	20th June	34.92	24.50	316	35.34	25.53	273	35.87	25.79	310
	30th June	34.44	24.05	198	34.81	25.02	297	35.50	25.26	284
	10th July	33.83	23.45	291	34.21	24.38	289	34.85	24.57	252
	20th July	33.55	22.79	225	33.88	23.67	267	34.54	23.95	205
	30th July	33.55	22.55	106	33.85	23.29	245	34.46	23.62	201
2016	10th June	35.21	25.80	667	36.30	26.34	546	37.12	26.87	300
	20th June	34.81	25.68	663	35.87	26.09	538	36.74	26.52	298
	30th June	34.58	25.02	605	35.53	25.41	426	36.35	25.79	337
	10th July	34.33	24.49	512	35.23	24.85	419	36.08	25.28	206
	20th July	34.13	24.02	355	35.10	24.33	276	35.86	24.77	170
	30th July	34.17	23.76	149	34.01	24.04	128	35.76	24.40	128

GRW=Gujranwala, HFD=Hafizabad, FSD=Faisalabad, TD[a]= Transplanting date, Max T= Maximum temperature, Min T= Minimum temperature

$$LAI = \frac{Leaf\ area}{Land\ area} ------ 1$$

$$CGR = \frac{W_2 - W_1}{T_2 - T_1} ------ 2$$

Where W_1 and W_2 are dry weights harvested at time interval of T_1 and T_2, respectively

***Radiation use efficiency (RUE)*:** Radiation use efficiency for biological yield (RUE_{BY}) (equation-3) and paddy yield (RUE_{PY}) (equation-4) was calculated as the ratio of total biomass and grain yield to cumulative intercepted photosynthetically active radiations (∑Sa) (equation-5) respectively.

$$RUE_{BY} = Biological \frac{yield}{\sum Sa} --- 3$$

$$RUE_{PY} = Paddy \frac{yield}{\sum Sa} --- 4$$

$$\sum Sa = Cumulative\ daily\ intercepted\ PAR --5$$

$$Daily\ intercepted\ PAR = \frac{Fi \times Daily\ total\ incident\ radiations}{2}$$

(Szeicz, 1974)

$$Fi = 1 - exp\ (-k \times LAI)$$

(Monteith and Elston, 1983)

Where 'k' is extinction coefficient for total solar radiations equal to 0.63 for rice (Ritchie *et al.,* 1998).

***Yield*:** Rice crop from 4 out of 8 rows was harvested at maturity by leaving the appropriate boarders to assess final yield. Paddy was sundried followed by oven dried at 70°C till constant weight after manual beat separation from panicle and then weighed and converted to kg ha^{-1}. Data were analyzed using analysis of variance technique and means were compared by Least Significance Difference (LSD) at 5% probability (Steel *et al.,* 1997).

RESULTS

***Phenology*:** Variation in rice phenology transplanted at different locations under different dates and seedling density is presented in Table 3. Considerable variations in phenology due to transplanting dates during both years were observed. The highest difference among the average of 2 years maximum and minimum days to tillering in all the selected transplanting dates at Gujranwala, Hafizabad and Faisalabad was 5 days. Comparatively, higher number of days to tillering was observed at Hafizabad in all transplanting dates and seedling per hill rates. Number of days to tillering at Hafizabad was followed by Faisalabad and Gujranwala in all transplanting dates. There was a gradual reduction in days to tillering with each succeeding transplanting date till 20th July. Unexpectedly, the number of days to tillering increased in 30th July transplanting date during both years. For transplanting density, average maximum difference in number of days to tillering observed at Gujranwala and Hafizabad in any transplanting date was 2 days. When transplanting dates were compared for days to anthesis at three locations, maximum average difference of 20 days was observed between 10th June and 30th July transplanted rice at Hafizabad during both years. Hafizabad also took least number of days to anthesis compared to Gujranwala and Faisalabad at each transplanting date and seedling density. More number of days to anthesis was observed in early transplanted rice. Number of days to anthesis indicated a decreasing trend with each successive transplanting date. Maximum average difference of both years for days to anthesis among the seedling densities within transplanting date of any location was only 2 days. It indicated that seedling per hill do not affect rice phenology to a greater extent. Both years average maximum days to physiological maturity (PM) among 3 locations were noted at Gujranwala followed by Faisalabad and Hafizabad in 10th June

Table 3. Phenology of rice as affected by location, transplanting date and number of transplanted seedling/hill during both years of experimentation

TD	PD	Days to tillering									Days to anthesis									Days to physiological maturity								
		Gujranwala			Hafizabad			Faisalabad			Gujranwala			Hafizabad			Faisalabad			Gujranwala			Hafizabad			Faisalabad		
		2015	2016	Avr.	2015	2016	Avr.	2015	2016	Avr.	2015	2016	Avr.	2015	2016	Avr.	2015	2016	Avr.	2015	2016	Avr.	2015	2016	Avr.	2015	2016	Avr.
10tth	1 P/H	22	21	22	25	23	24	23	22	23	90	85	88	88	85	87	90	86	88	122	122	122	118	118	118	119	120	120
June	2 P/H	22	21	22	25	23	24	23	22	23	91	84	88	89	86	88	89	87	88	121	120	121	117	118	118	119	119	119
	3 P/H	23	22	23	26	25	26	24	23	24	91	85	88	89	86	88	89	87	88	122	123	123	118	119	119	120	121	121
20th	1 P/H	21	20	21	24	23	24	22	21	22	83	80	82	79	78	79	80	80	80	116	114	115	112	109	111	114	112	113
June	2 P/H	21	21	21	24	23	24	22	21	22	84	81	83	80	78	79	79	81	80	117	116	117	113	111	112	114	114	114
	3 P/H	21	21	21	24	23	24	22	21	22	85	81	83	80	80	80	81	81	81	118	117	118	114	112	113	116	115	116
30th	1 P/H	20	20	20	23	22	23	21	20	21	79	76	78	78	74	76	79	79	79	116	113	115	112	108	110	113	111	112
June	2 P/H	19	19	19	23	22	23	21	20	21	79	77	78	79	76	78	81	81	81	117	114	116	113	109	111	114	112	113
	3 P/H	19	20	20	23	23	23	21	20	21	80	78	79	79	76	78	83	80	82	117	115	116	113	110	112	114	113	114
10th	1 P/H	19	19	19	22	21	22	20	20	20	79	72	76	75	71	73	77	76	77	112	109	111	108	104	106	109	107	108
July	2 P/H	19	19	19	22	21	22	20	20	20	79	73	76	76	72	74	79	78	79	113	110	112	109	105	107	109	108	109
	3 P/H	19	20	20	22	22	22	20	21	21	79	74	77	76	72	74	79	79	79	112	110	111	108	105	107	109	108	109
20th	1 P/H	18	18	18	21	21	21	19	19	19	78	70	74	75	668	372	76	73	75	106	103	105	102	98	100	104	101	103
July	2 P/H	18	18	18	21	21	21	19	19	19	78	71	75	75	69	72	77	74	76	107	104	106	103	99	101	105	102	104
	3 P/H	19	19	19	22	21	22	20	20	20	78	71	75	75	71	73	77	73	75	109	104	107	105	99	102	107	102	105
30th	1 P/H	19	21	20	23	23	23	21	21	21	73	67	70	70	64	67	71	69	70	97	93	95	93	88	91	94	91	93
July	2 P/H	19	21	20	23	24	24	21	22	22	74	68	71	71	65	68	72	70	71	97	94	96	93	89	91	95	92	94
	3 P/H	20	21	21	23	24	24	21	22	22	73	69	71	70	65	68	71	70	71	98	93	96	94	88	91	97	91	94

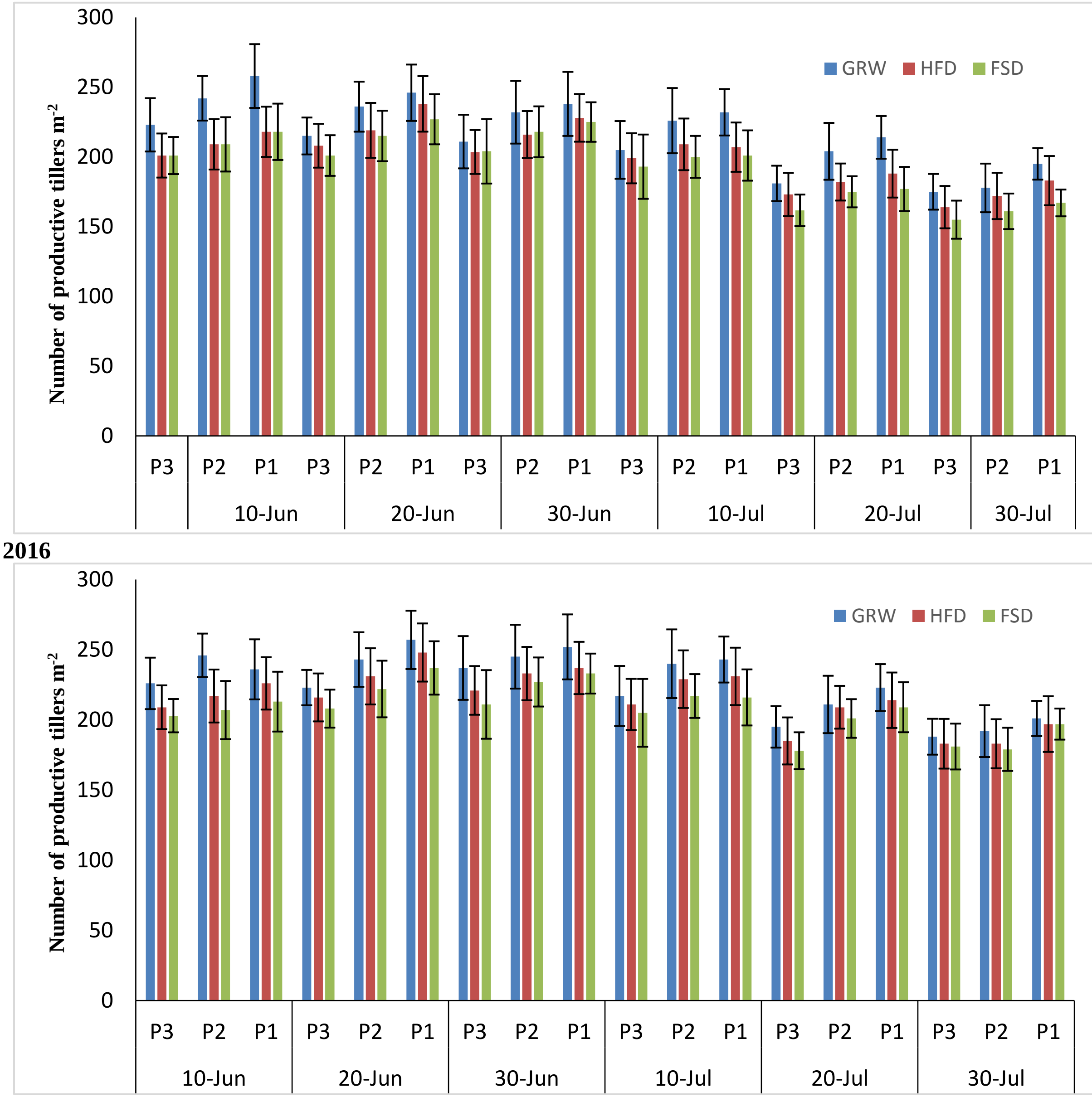
TD= transplanting date, PD=number of transplanted seedling per hill, P/H=Plant per hill

transplanted rice at the rate of 3 seedlings per hill. At all locations, the number of days to physiological maturity went on decreasing with each succeeding transplanting date. During both years, mean minimum number of days to physiological maturity were recorded in 30th July transplanted rice.

***Productive tillers (m^{-2})*:** Ability of Basmati-515 to produce panicle bearing tillers differed significantly among locations, transplanting dates and densities during both years experiment (Figure 1 a and b). Maximum tillers m^{-2} (217 during 2015 and 226 during 2016) was counted at Gujranwala while the minimum at Faisalabad (195 and 207 with respect to years). In 1st year experiment, Hafizabad and Faisalabad were at par with respect to tillers m^{-2} while in 2nd year, Gujranwala and Hafizabad as well as Hafizabad and Faisalabad indicated similar behavior. Among transplanting dates, 20th June (223) and 30th June (232) were the highest tillers producing dates in 2015 and 2016 respectively. The 30th July was the lowest tillers m^{-2} producing date in both years (172 during 2015 and 188 during 2016). In 2015 tillers m^{-2} of 1st three consecutive dates (10thJune, 20th June and 30th June) were at par while during 2016 tillers m^{-2} of 20th June, 30th June, and 10th July were at par and as were the tillers of 10th June and 10th July. Number of tillers m^{-2} increased with increasing per hill seedling density. During both years, maximum tillers m^{-2} were observed in 3-seedling per hill (214 during 2015 and 225 during 2016) while the minimum in 1-seedling per hill (193 during 2015 and 205 during 2016).

***Leaf area index (LAI)*:** Locations did not differ significantly for LAI but transplanting dates and seedling densities differed significantly. Non-significant effect of locations on LAI indicates that the leaf growth remains constant even after environmental variations. During 2015, maximum LAI was observed in 20th June (6.01) transplanted rice that was at par with 10thJune, 30th June and 10th July while the minimum LAI was observed in 30th July (4.29) transplanted rice. During 2016, maximum but equivalent LAI recorded in10th and 20th June (6.09) was at par with 30th June and 10th July transplanted rice. During this year minimum LAI was recorded in 30th July transplanted rice. Decreasing leaf area was due to reduction in growth period with each successive transplanting date. During 2015, maximum (5.73) and minimum (5.20) LAI were recorded in 3 and 1 seedling per hill transplanting density respectively and similar was the trend during 2016 (5.88 maximum in 3-seedling and 5.28 minimum in 1-seedling per hill). The significant effects of locations and transplanting dates on LAI were also reported by Ahmad *et al.* (2009) which support the findings of current study.

***Crop growth rate (CGR)*:** Significant variations among locations, transplanting dates and seedling density for CGR were observed during both years. Maximum CGR during 2015 and 2016 was observed at Gujranwala (25.45 g m^{-2} day^{-1} and 25.16 g m^{-2} day^{-1} with respect to year) while the minimum at Faisalabad (20.85 g m^{-2} day^{-1} and 22.68 g m^{-2} day^{-1} with respect to year). This locational variability in CGR is associated with more rainfall and better adaptability of rice at Gujranwala compared to Hafizabad and Faisalabad. Among transplanting dates, 20th July attained maximum CGR during 2015 (28.42 g m^{-2} day^{-1}) and 2016 (29.46 g m^{-2} day^{-1}) while minimum CGR during 1st and 2nd year was attained by 10th July (20.32 g m^{-2} day^{-1}) and 20th July (20.27 g m^{-2} day^{-1}) transplanted rice, respectively. For seedling density, maximum CGR during 2015 and 2016 was observed in 3-seedlings per hill (24.11 g m^{-2} day^{-1} and 24.54 g m^{-2} day^{-1} with respect to year) while the minimum in 1-seedling per hill



GRW=Gujranwala, HFD=hafizabad, FSD= Faisalabad: P_1, P_2 ,P_3= 1, 2 and 3 seedings per hill

Figure 1. Effect of transplanting date and number of transplanted seedling per hill on the number of productive tillers per m^{-2} during 2015 and 2016

transplanted rice (22.66 g m^{-2} day^{-1} and 22.99 g m^{-2} day^{-1} with respect to year).

***Paddy yield (kg ha^{-1})*:** Substantial variations in paddy yield were observed at selected locations, transplanting dates and seedling densities during both years. During 2015 and 2016 maximum paddy yield was recorded at Gujranwala (3148 kgha^{-1} and 3350 kgha^{-1} respectively). While, the minimum paddy yield was recorded at Faisalabad during both years (2780 kgha^{-1} and 3002 kgha^{-1}, respectively). Both years yields at Gujranwala and Hafizabad were at par and similar were the yields at Hafizabad and Faisalabad during 2015. Some of the observed reasons behind highest yield recorded at Gujranwala were, it is a location situated in core rice area with plenty of rainfall and well-suited temperatures. Considering the transplanting dates, 30th June during both years produced maximum (3586 kg ha^{-1} during 2015 and 3789 kg ha^{-1} during 2016) while 30th July with minimum (3586 kg ha^{-1} during 2015 and 3789 kgha^{-1} during 2016) yield. Among seedling density, during 2015 (3080 kgha^{-1}) as well as 2016 (3291 kg ha^{-1}) 3-seedlings per hill was the top yield producer while 1-

Table 4. Growth and yield parameters as affect by transplanting date, number of transplanted seedling per hill and location during 2015 and 2016.

	Location	LAI			CGR (g m^{-2} day^{-1})			Yield (kg ha^{-1})			RUE$_{PY}$ (g MJ^{-1})			RUE$_{BY}$ (g MJ^{-1})		
		2015	**2016**	**Avr.**	**2015**	**2016**	**Avr.**	**2015**	**2016**	**Avr.**	**2015**	**2016**	**Avr.**	**2015**	**2016**	**Avr.**
	Gujranwala	5.52	5.60	5.56	25.54a	25.16a	25.35	3148a	3350a	3249	1.18a	1.34a	1.26	4.94a	5.51a	5.23
	Hafizabad	5.44	5.57	5.51	23.92b	23.64b	23.78	2971ab	3180ab	3076	1.19a	1.27a	1.23	4.89a	5.04b	4.97
	Faisalabad	5.41	5.57	5.49	20.85c	22.68c	21.77	2780bc	3002bc	2891	1.09b	1.18b	1.14	4.50b	4.87b	4.69
	LSD 5%	0.35	0.37		0.89	0.63		235	212		0.09	0.05		0.28	0.36	
	Significance	NS	NS		**	**		*	*		*	**		*	*	
Trans-planting date	10th June	6.00a	6.09a	6.0	20.32c	20.42d	20.37	2533c	2761c	2647	0.85d	0.93e	0.89	4.38c	6.36d	5.37
	20th June	6.01a	6.09a	6.05	20.47c	20.27d	20.37	3488a	3702a	3595	1.23b	1.35bc	1.29	4.62bc	4.95cd	4.79
	30th June	5.82a	5.86a	5.86	23.68b	24.27bc	23.98	3586a	3789a	3688	1.32a	1.43a	1.38	4.81ab	5.16bc	4.99
	10th July	5.62a	5.79a	5.79	24.01b	23.23c	23.62	3260b	3465b	3363	1.30a	1.40a	1.35	4.89a	5.32ab	5.11
	20th July	5.02b	5.14b	5.14	28.42a	29.46a	28.94	2647c	2852c	2750	1.13c	1.27cd	1.20	4.96a	5.49a	5.23
	30th July	4.29c	4.52c	4.52	23.68b	25.32b	24.50	2286d	2491d	2389	1.08c	1.21d	1.15	4.98a	5.28ab	5.13
	LSD 5%	0.39	0.31		1.27	1.39		184	193		0.07	0.08		0.25	0.32	
	Significance	**	**		**	**		**	**		**	**		**	**	
Trans-planting density	1 seedling/hill	5.20c	5.28c	5.28	22.66b	22.99b	22.83	2864c	3072c	2968	1.12b	1.23b	1.18	4.57c	4.92c	4.75
	2 seedling/hill	5.45b	5.59b	5.59	23.54a	23.96a	23.75	3080a	3291a	3186	1.20a	1.30a	1.25	4.75b	5.15b	4.95
	3 seedling/hill	5.73a	5.88a	5.88	24.11a	24.54a	24.33	2955b	3169b	3062	1.15b	1.26b	1.21	4.95a	5.33a	5.14
	LSD 5%	0.21	0.17		0.73	0.78		91	95		0.03	0.03		0.17	0.16	
	Significance	**	**		**	**		**	**		**	**		**	**	

NS=Not significant, *=significant, **=highly significant

seedling per hill the lowest (2955 kg ha^{-1} and 3169 kgha^{-1} with respect to year). High yield recorded at 3-seedlings per hill was due to more number of tillers, more panicles and more number of grains per unit area

Paddy yield radiations use efficiency (RUE$_{PY}$): Transplanting date is one of the agronomic practices that affected intercepted photosynthetically active radiations and ultimately the radiations use efficiency of rice Locations, transplanting dates and planting densities were significant in terms of paddy yield radiations use efficiency (RUE$_{PY}$).Among locations, during 2015 maximum (1.19 g MJ^{-1}) RUE$_{PY}$ recorded at Hafizabad was at par with RUE$_{PY}$ of Gujranwala while the minimum (1.09 g MJ^{-1}) RUE$_{PY}$ was recorded at Faisalabad. During 2016, maximum (1.34 g MJ^{-1}) PY$_{RUE}$ recorded at Gujranwala was at par with PY$_{RUE}$ of Hafizabad while the minimum (1.18 g MJ^{-1}) RUE$_{PY}$ was recorded at Faisalabad. Among transplanting dates, rice of 30th June during 2015 (1.32 g MJ^{-1}) and 2016 (1.43 g MJ^{-1}) gave maximum RUE$_{PY}$ while the minimum of it during 2015 (0.85 g MJ^{-1}) and 2016 (0.93 g MJ^{-1}) was recorded in 10th June transplanted rice. PY$_{RUE}$ of 30th June and 10th July, and 20th and 30th July during both years were at par. Among the seedling density, maximum RUE$_{PY}$ during both years was recorded at 2-seedlings per hill (1.20 g MJ^{-1}) and 1.30 g MJ^{-1} with respect to year) while the minimum in 1-seedling per hill during both years (1.12 g MJ^{-1} and 1.23 g MJ^{-1} with respect to year).

Biological yield radiations use efficiency (RUE$_{BY}$): Locations were significant while transplanting dates and planting densities were highly significant in terms of biological yield radiations use efficiency (RUE$_{BY}$). During 2015 (4.94 g MJ^{-1}) and 2016 (5.51 g MJ^{-1}) maximum RUE$_{BY}$ was recorded at Gujranwala while the minimum at Faisalabad (4.50 g MJ^{-1} and 4.87 g MJ^{-1} with respect to year). During 2015 RUE$_{BY}$ at Gujranwala and Hafizabad was at par and similar trend was observed in RUE$_{BY}$ at Hafizabad and Faisalabad during 2016. Among transplanting dates, 30th July during 2015 (4.98 g MJ^{-1}) and 10th June during 2016 (6.36 g MJ^{-1}) attained maximum RUE$_{BY}$ while the minimum of it during 2015 (4.38 g MJ^{-1}) and 2016 (4.95 g MJ^{-1}) was recorded in 10th June and 20th June transplanted rice, respectively. Among the seedling density maximum RUE$_{BY}$ during both years was recorded at 3-seedlings per hill (4.95 g MJ^{-1} and 5.33 g MJ^{-1} with respect to years) while the minimum in 1-seedling per hill during both years (4.57 g MJ^{-1} and 4.92 g MJ^{-1} with respect to year.

DISCUSSION

Among the rice yield deciding factors transplanting date and plant population per unit area can never be ignored. To investigate the effect of these factors a multi-location trial was conducted to study the effect of transplanting date and number of transplanted seedlings per hill on rice phenology, growth, yield and yield related factors.

Phenology played an important role in rice yield. It was much affected by variations in temperature. Different transplanting dates exposed the rice crop to different average temperatures (Table 2). At each location with successive transplanting date the number of days taken to each phenological event (tillering, panicle initiation and physiological maturity) went on decreasing and as was the average temperature. The effect of temperature on development and phenology of rice is well documented by Andrej *et al.* (2011) and Tao *et al.*(2012). High temperature in early transplanting dates increased the vegetative growth of the crop throughout the season by increasing the time span between two successive phonological events but also enhanced sterility with negative impact on paddy yield, while low temperature in later transplanting dates reduced the yield by squeezing the time span between each phenological event and ultimately the total life span of the crop. Farrell *et al.* (2006) reported that cold temperature has significant negative effect on rice yield which supported the current study. In a study conducted by Safdar *et al.* (2013) number of days to maturity indicated a decreasing trend with each successive transplanting date identical to the present study. More number of day to anthesis in early compared to late transplanted rice were also reported by Moradpour *et al.* (2013). The late transplanted rice took more days to tillering. It might be due to low night temperature exposure in 30th July transplanted rice during the month of August which increased the number of days to tillering. The effects of transplanting date and transplanting density on the number of productive tillers were also significant. The Significant effect of transplanting dates on number of tillers was also reported by Akram *et al.* (2007) and Sarwar *et al.* (2008). Delay in rice transplanting resulted significant decrease in number of productive tillers per m^{-2} and ultimately the paddy yield (Rakesh and Sharma, 2004). Safdar *et al.* (2013) founded decreasing number of productive tiller per unit area with successive transplanting date. The number of fertile tillers was also decreased with increasing transplanting density in a study conducted by Mobasser *et al.* (2012) and Amin *et al.* (2012). There was an insignificant effect of plant population on the number of productive tillers in a study conducted by Bagayoko (2012). All these studies supported the results of current trial.

Top paddy yield produced at Gujranwala was associated with more rainfall during 2016 as compared to Hafizabad and Faisalabad. Furthermore, the high yield may also be associated with most suitable edaphic factors of Gujranwala for rice crop. Reason of low yield recorded at 10th and 20th June was the high temperature during growth and development and its subsequent effect on panicle size, number of filled grains per panicle and 1000-grain weight, while low yield recorded during 20th and 30th July was due to low temperature during rice economical part development and poor photosynthates accumulation due to squeezed growth period. Yield of rice transplanted on 20th and 30th June during both years was at par which indicated that these two dates and time between the two dates were best for rice sowing. High yield in rice was obtained when sown at an optimum date (Iqbal *et al.*, 2008; Osman *et al.*, 2012). .Early and late transplanting resulted in declined yield of rice in a study conducted by Lack *et al*. (2012), Brar *et al*.(2012), Khalifa *et al.* (2014) and Osman *et al.* (2015).There was a reduction in paddy yield with increasing planting density in the study of Mobasser *et al.* (2012) and Amin *et al.* (2012).

In the present study, crop growth rate indicated a decreasing trend with each successive transplanting date in any of the number of transplanted seedlings per hill at all locations. But in an experiment conducted by Moradpour *et al.* (2013) in Iran to investigate the effect of planting dates (30th May, 9th June and 19th June) on the crop growth of rice it was indicated that crop growth rate increased with delaying transplanting. In this study, 19th June was the best performing transplanting date of rice. This contradiction might be due to different environmental conditions. Crop growth rate dynamics associated with transplanting date and plant population were also reprted by Ahmad *et al.* (2009), Lin *et al.* (2009) and Ahmad and Hasanuzzaman (2012). In a study conducted by Ahmad *et al.* (2009), the radiation use efficiency was increased in later transplanting dates as in the current study.

One of the improved cultural practices is the number of transplanted seedlings per hill. Optimum plant population played critical role in boosting the yield via increasing resources (light interception, nutrients and related physiological phenomina) use efficiency. Plant population above optimum increased inter-specific competition, made crop more prone to lodging, increased biomass and reduced the yield (Faruk *et al.*, 2009). Significant variation in LAI with variable number of seedlings per hill was due to varying total leaf area production in 1 and 3-seedling per hill transplanted rice. It was observed that with increasing transplanting density number of leaves, panicle length and culm length were decreased and consequently the leaf area per plant (Fukushima *et al.*, 2011). But on unit area basis, leaf area increased with increasing planting density and as was observed in the present study. Similar conclusion was also discussed in a study conducted by Mondal *et al.* (2013). Faruk *et al.* (2009) recorded maximum yield from two seedlings per hill transplanted rice. Bozorgi *et al.* (2011) found that highest grain yield was obtained from 3-seedlings per hill while the lowest in 1-seedling per hill. Differential planting density affected days to anthesis and maturity (Vilayvong *et al.*, 2015). But in current study no such effect was observed. While, the significant effect of number of seedlings per hill on number of productive tillers was also reported by Sarkar *et al.* (2011).

***Conclusion*:** It is concluded from the present study that rice performance is affected considerably at different locations, transplanting dates and transplanting densities. Among the selected 3 location, 6 transplanting date and 3 transplanted seedling per hill, Gujranwala, 30th June and 2 seedling per hill performed best in terms of yield, yield contributing factors and growth factors. On the basis of the findings of the current study it is recommended that basmati-515 should be transplanted at all the selected locations within the time span of 30th June to 10th July at the rate of 2 seedlings per hill transplanting density.

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