IMPROVING GROWTH AND DEVELOPMENT OF RICE CULTIVARS THROUGH MANAGEMENT PRACTICES

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Abstract- Management practices are a pre requisite for vigorous growth and development of rice crop. A field experiment was therefore conducted to evaluate the effectiveness of different management practices for growth and development of different rice cultivars. A two year experiment was conducted with two management practices i.e. seedling age (25, 35 and 45 days) and seedling densities (1, 3 and 5 seedlings hill^{-1}) tested on three rice cultivars (JP-5, Fakhr e Malakand and Swati-2014). The research cite Agriculture Research Institute (North) Swat. Various growth parameters like leaf area, leaf area index and plant height was observed during the research. The results of the experiment indicated that JP-5 variety produced taller plants compared to other varieties. Leaf area and leaf area index recorded at different intervals i.e. 30 days after transplantation (DAT), panicle initiation and maturity stages, were higher in Fakhr e Malakand. Among different seedling ages, taller plants were observed with transplanting 35 days old seedling. Similarly leaf area and leaf area index at panicle initiation and maturity stages were higher with transplanting either 25 or 35 days older seedling. Leaf area at 30 DAT was higher with 45 days older seedling, while leaf area at 30 DAT was not considerably affected. In case of different seedling densities, transplanting single seedling increased plant height and leaf area at all stages. Leaf area index at all stages was higher by transplanting 5 seedling hill^{-1}. It is concluded that cultivation of Fakhr e Malakand variety at seedling age of either 25 or 35 days at transplanting density of single seedling hill^{-1} improved rice growth and development.

Key words- rice, management practices, seedling desnisty, seedling age, growth

I. INTRODUCTION

Rice (*Oryza sativa* L.) is an important agricultural crop, which has an important role in the economy of Pakistan. It is the third largest cereal crop and is also regarded as cash crop of Pakistan in terms of area after wheat and cotton that earns billons of rupees for the country through its export. In Pakistan 2.9 million hectares area was under rice cultivation with 7.5 million tons production with average yield of 2568 kg ha^{-1} (Agriculture Statistics of Pakistan, 2017-18). In Khyber Pakhtunkhwa, rice was cultivated on an area of around 61.6 thousand hectares with 147.5 thousand tons of annual production with average yield of 2394 kg ha^{-1} (Agriculture Statistics of Pakistan, 2017-18).

Rice is grown under wide range of edaphic and climatic conditions. In Punjab, Basmati rice predominates in traditional rice tracts. Temperate Japonica rice is grown in high altitude of Khyber Pakhtunkhwa (Swat and Mansehra). However, Irri type long grain rice tolerant to heat is mostly cultivated in southern part of KPK, Sindh and a part of Balochistan. Pakistan ranks 13th in the production,while fourth in the export of rice worldwide (FAO, 2018).

In Pakistan mostly two types of rice varieties are grown i.e. fine (Basmati) and coarse grain (Irri.). Fine grain varieties are late maturing and coarse grain varieties are early maturing. Punjab is the major province for rice production in the country where farmers prefer fine grain (Basmati) for cultivation as the quality and aroma of fine grain varieties is higher, growing conditions are suitable and consumer demand is greater as compared to coarse grain varieties. Approximately, 63% of the total area under rice cultivation is occupied by Basmati, 22% of the total area is cultivated with coarse rice and the remaining 15% area is cultivated with other varieties (Agriculture Statistics of Pakistan, 2017-18).

Besides other production variables, selection of proper genotype is the most and first factor that affect yield and quality of rice. Varieties, affect the growth and performance as well as the yield related characters of paddy crop. There exist significant differences in number of tillers and plant heights among different varieties in a season (Miah et al., 2004). Crop productivity is severely affected by various environmental circumstances like solar radiation interception, temperature and availability of water during crop growth and development (Fageria, 2007). Ahmad et al. (2009) stated that potential crop yield partly depends upon the interception of photo active radiations, which is strongly influenced by leaf area and leaf area index (Muchow and Carberry, 1989). Such growth characters like leaf area and leaf area index are affected by crop genotype, nutrition and planting density (Ahmad et al., 2009).

On the other hand, management practices that deals with the seedlings transplantation are of prime importance including the seedling's optimum age and the appropriate number of seedlings hill^{-1} for improving rice yield and quality. Seedling age has a tremendous effect on the tillers production, plant height, grains panicle^{-1}, panicle's length, grain formation and other yield contributing characters (Chapagain and Yamaji, 2010). Appropriate age of seedlings is essential for obtaining the uniform stand establishment. Younger seedlings perform better than older seedlings (Patra and Haque, 2011).

Seedling age is of prime importance because it has direct detrimental effect on crop growth and development, tillering ability, grain formation and yield contributing factors of rice (Saphi and Yadav, 2019). Different researchers reported contradictory results about the exact age of seedling. However, most of the researchers reported higher yield can be obtained by transplanting seedling of 25 days (Nandinin and Singh, 2000; Thanunathan and Sivasubramanian, 2002).

II. MATERIALS AND METHODS

The research was carried out at Agricultural Research Institute (North), Mingora during, summer-2018 and was repeated in summer-2019. This research was comprised of three factors. Varieties as factor A, three different varieties i.e. JP-5, Fakhr e Malakand and Swati-2014 were tested. The second factor of the research was seedling ages, three seedling ages were observed i.e. 25, 35 and 45 days older seedling were tested. The third and last factor of the experiment was seedling density hill^{-1}. Three seedling densities i.e. 1, 3 and 5 seedlings hill^{-1} were tested. Randomized complete block design with split plot arrangements were used with varieties and seedling ages as main plot factors and seedling density as subplot factors. The research was conducted in four replication. Different agronomic practices like fertilization, weeding, irrigation and pest control were kept uniform for all the treatments. Plot size was 4m x 3m with row to row and plant to plant distance of 20 cm.

Treatment combinations of the levels of factor-A (variety) and factor-B (seedling's age) were randomly allotted to main plots while number of seedlings hill^{-1} were randomly allotted to the subplots. Field was thoroughly prepared with the help of cultivator by two to three ploughings followed by planking and one ploughing in the standing water. Nitrogen, phosphorus, potassium and zinc were incorporated in the soil at the recommended rate of 100: 60: 40 and 10 kg ha^{-1} by mixing Urea, SSP, MOP, and Zinc Sulphate, respectively as a basal dose to each subplot. Each of the half nitrogen and full dose of phosphorus and potash were mixed in the soil at first ploughing, while the other half of nitrogen was applied after about 30 days post sowing. However, zinc was applied after one week of transplantation. Nursery was sown during both the years.

Nursery Sowing

In order to achieve desired seedling age, nursery sowing time was altered. 1st nursery was sown on 15th May, followed by 25th May and the last nursery was sown on 4th June.

Seedling Age

In Factor B, 1st seedlings were transplanted from nursery sown on 4th June to the main plots after 25-days of sowing. The 2nd seedlings were transplanted after an interval of 35-days post nursery sowing from the nursery sown on 25th May, while the 3rd seedlings were transplanted at the age of 45-days post nursery sowing from the nursery sown on 15th May.

Transplantation

Transplantation was done on same date in the standing water (3 to 4 cm) in each subplots from those nurseries and the water was allowed to stand up to 8 cm after one week of transplantation. Standing water was replaced at one month interval in each subplot and was drained before 15 days to physiological maturity. For weed and insect/pest control, Furadan (insecticides) was applied ten days after transplantation while, Machette (weedicides) within three days after transplantation, respectively. For all subplots, standard agronomic practices were uniformly adopted as required.

Observations

Data were recorded on plant height, leaf area and leaf area index at different intervals i.e. 30 days after transplantation, panicle initiation and physiological maturity stage

Statistical analysis

For analysis of the obtained data in accordance with RCBD split plot arrangement, the computer software Statistix 8.1 was used. Further, means and their differences were separated by applying Least significant difference (LSD) test (Steel and Torrie, 1980).

III. RESULTS

A. *Plant height (cm)*

Plant height of different rice varieties (V) as influenced by various seedling ages (SA) and transplanting density hill^{-1} (SH) are shown in Table 1. Statistical analysis of the data shown that different rice varieties produced plants with significantly different height. Similarly, plant height of rice was considerably affected by varying seedling age and transplanting density hill^{-1}. Means of the data concerning varieties indicated that taller plants (128 cm) were produced by variety JP-5, which was followed by Swati-2014 (112 cm). Short statured plants (108 cm) were produced by Fakhr e Malakand. Among different levels of seedling age, increasing seedling age up to 35 days increased plant height and further increase in seelding age decreased plant height. Taller plants (121 cm) were produced with 35 days old seedling as compared to 25 or 45 days old seedling (114 cm). Among different levels of transplanting density hill^{-1}, increasing transplanting density decreased plant height. Taller plants (120 cm) were observed with transplanting density of single seedling hill^{-1}, which was followed by transplanting 3 seedling hill^{-1} (117 cm). Shorter plants (111 cm) were observed by transplanting 5 seedling hill^{-1}. The year effect was nonsignificant for plant height. The interaction effects V x SH, SA x SH and V x SA x SH were found significant for plant height. The interaction V x SH indicated that increasing planting density hill decreased plant height in all three varieties, however a slight increase was observed in JP-5 at 3 seedling hill^{-1} (Fig. 1). The interaction SA x SH revealed that increasing seedling age with increasing transplanting density hill^{-1} decreased plant height, but the decrease was more prominent with transplanting 3 seedling hill^{-1} (Fig. 2). The interaction V x SA x SH indicated that increasing seedling age and transplanting density decreased plant height in all three varieties, however in JP-5 slight increase was observed with increasing seedling age up to 35 days at 3 seedling hill^{-1} while in Swati-2014 slight increase was observed with 35 days seedling age at all transplanting densities (Fig. 3).

B. *Leaf area tiller^{-1} (cm^2) after 30 days of transplantation*

Leaf area tiller^{-1} at 30 days after transplantation of rice varieties (V) as influenced by different levels of seedling ages (SA) and seedling density hill^{-1} (SH) are presented in Table 2. Leaf area tiller^{-1} after 30 days of transplantation was significantly different in the varieties tested. The effect of seedling ages and seedling density hill^{-1} were also found significant for leaf area after 30 days of transplantation. The interaction V x SA was found significant, while the rest of interactions were not significant. The leaf area tiller^{-1} after 30 days of transplantation was significantly different in both years, greater leaf area was recorded in 2019 as compared to 2018. Mean values of the varieties indicated greater leaf area tiller^{-1} (60.4 cm^2) after 30 days of transplantation in Fakhr e Malakand, which was followed by JP-5 (57.6 cm^2). Minimum leaf area (56.9 cm^2) was noticed in Swati-2014. Among different seedling ages, older seedling produced maximum leaf area tiller^{-1}. The greatest leaf area (60.2 cm^2) was observed with 45 days older seedling, followed by 35 days older seedling (58.6 cm^2). Minimum leaf area (56.1 cm^2) was noticed with 25 days old seedling. In case of seedling density hill^{-1}, greater leaf area (62 cm^2) was recorded with transplanting single seedling hill^{-1}, which was followed by transplanting 3 seedling hill^{-1} (58.4 cm^2). Lower leaf area (54.4 cm^2) was observed with transplanting 5 seedling hill^{-1}. The interaction V x SA indicated that increasing seedling age increased leaf area in all three varieties, however the increase was more prominent by increasing seedling age beyond 35 days in JP-5 (Fig. 4).

Table 1. Plant height (cm) of rice varieties as influenced by different seedling age and number of seedling hill^{-1}.

	Year		
Varieties (V)	2018	2019	Means
Fakhr e Malakand	107	109	108 c
JP-5	127	130	128 a
Swati-2014	111	113	112 b
LSD for V	6	6	4
Seedling Ages (SA)			
25 days	113	115	114 b
35 days	119	122	121 a
45 days	113	115	114 b
LSD for SA	6	6	4
Seedling Hill^{-1} (SH)			
1	119	121	120 a
3	115	118	117 b
5	110	112	111 c
LSD for SH	5	5	3
Year			
2018			115
2019			117
Significance			Ns
Interactions	Significance	Interactions	Significance
V x SA	ns	V x SA x SH	**
Y x V	ns	Y x SH	Ns
Y x SA	ns	Y x V x SH	Ns
Y x V x SA	ns	Y x SA x SH	Ns
V x SH	**	Y x V x SA x SH	Ns
SA x SH	*		

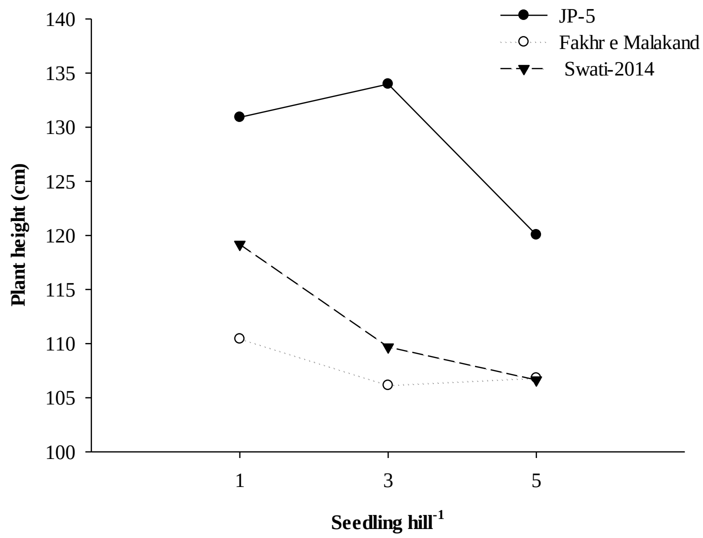

Fig. 1. Interaction V x SH for plant height

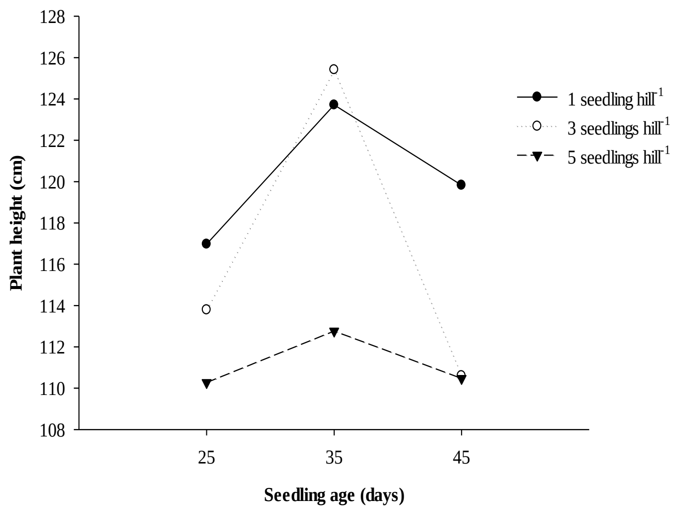

Fig. 2. Interaction SA x SH for plant height

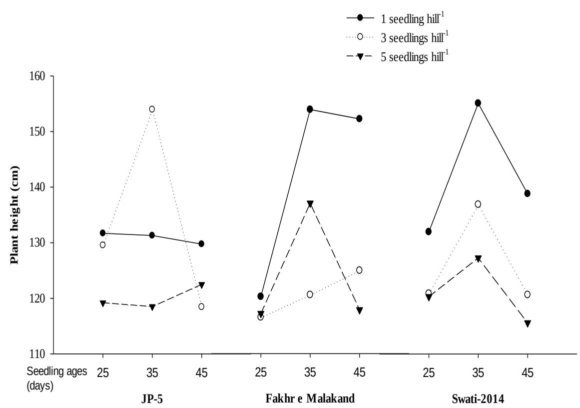

Fig. 3. Interaction V x SA x SH for plant height

Table 2. Leaf area tiller^{-1} (cm^2) after 30 days of transplantation of rice varieties as influenced by different seedling age and number of seedling hill^{-1}.

	Year		
Varieties (V)	2018	2019	Means
Fakhr e Malakand	58.2	62.7	60.4 a
JP-5	55.0	60.2	57.6 b
Swati-2014	55.3	58.4	56.9 b
LSD for V	2.6	2.7	1.8
Seedling Ages (SA)			
25 days	54.4	57.9	56.1 c
35 days	56.1	61.1	58.6 b
45 days	58.1	62.3	60.2 a
LSD for SA	2.6	2.7	1.8
Seedling Hill^{-1} (SH)			
1	60.1	63.9	62.0 a
3	56.3	60.6	58.4 b
5	52.1	56.7	54.4 c
LSD for SH	2.6	2.5	1.8
Year			
2018			56.2 b
2019			60.4 a
Significance			**
Interactions	Significance	Interactions	Significance
V x SA	**	V x SA x SH	Ns
Y x V	ns	Y x SH	Ns
Y x SA	ns	Y x V x SH	Ns
Y x V x SA	ns	Y x SA x SH	Ns
V x SH	ns	Y x V x SA x SH	Ns
SA x SH	ns		

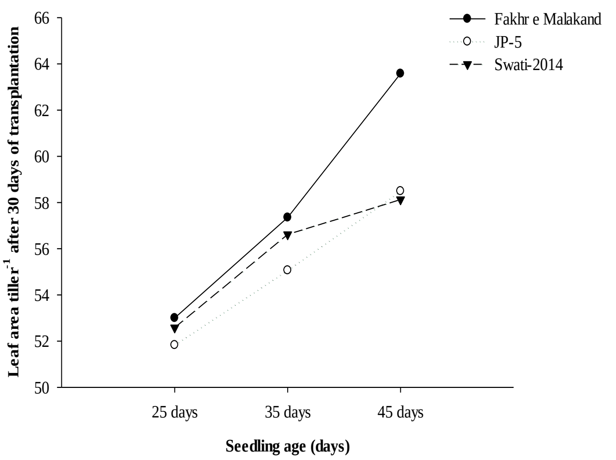

Fig. 4. V x SA interaction for leaf area tiller^{-1} after 30 days of transplantation

C. *Leaf area tiller^{-1} (cm^2) at panicle initiation*

The effect of different seedling ages (SA) and seedling density hill^{-1} (SH) on leaf area tiller^{-1} at panicle initiation of rice varieties (V) is given in Table 3. Statistical analysis of data indicated that leaf area of different rice varieties was significantly different at panicle initiation. Similarly, the effect of seedling ages and seedling density was also found significant. The interaction V x SA was found significant, while the rest of interactions were not significant. Year as source of variation was also found significant and greater leaf area tiller^{-1} at panicle initiation was observed in 2019 as compared to 2018. non-significant. Among three varieties, Fakhr e Malakand produced greater leaf area tiller^{-1} (143 cm^2) at panicle initiation, followed by Swati-2014 (133 cm^2). The minimum leaf area (129 cm^2) were recorded in JP-5. In case of seedling ages, greater leaf area (139 cm^2) was recorded with 35 days older seedling which was statistically at par with leaf area produced by 25 days old seedlings (136 cm^2). Minimum leaf area was (130 cm^2) recorded with 25 days old seedling.

Table 3. Leaf area tiller^{-1} (cm^2) at panicle initiation of rice varieties as influenced by different seedling age and number of seedling hill^{-1}.

	Year		
Varieties (V)	2018	2019	Means
Fakhr e Malakand	136	150	143 a
JP-5	124	135	129 c
Swati-2014	129	138	133 b
LSD for V	6	6	4
Seedling Ages (SA)			
25 days	130	143	136 a
35 days	134	144	139 a
45 days	125	136	130 b
LSD for SA	6	6	4
Seedling Hill^{-1} (SH)			
1	138	149	144 a
3	128	140	134 b
5	122	134	128 c
LSD for SH	5	5	4
Year			
2018			130 b
2019			141 a
Significance			**
Interactions	Significance	Interactions	Significance
V x SA	**	V x SA x SH	ns
Y x V	ns	Y x SH	ns
Y x SA	ns	Y x V x SH	ns

Y x V x SA	ns	Y x SA x SH	ns
V x SH	ns	Y x V x SA x SH	ns
SA x SH	ns		

Among various levels of seedling density hill^{-1}, increasing seedling density reduced leaf area and higher leaf area (144 cm^2) was recorded with transplantation of single seedling which was followed by transplantation of 3 seedling hill^{-1} (134 cm^2). The leaf area (128 cm^2) was minimum with transplanting 5 seedlings hill^{-1}. The interaction between varieties and seedling age (V x SA) revealed that increasing seedling age up to 35 days increased leaf area in all varieties and further increasing seedling ages reduced leaf area in JP-5 (Fig. 5).

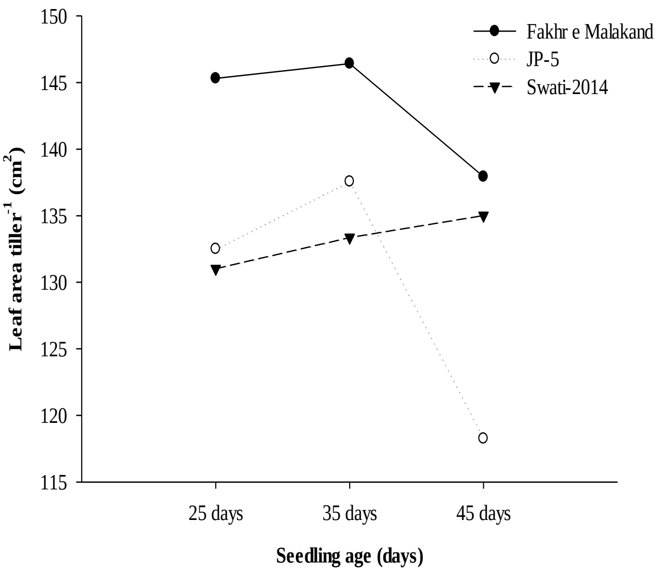

Fig. 5. Interaction V x SA for leaf area tiller^{-1} at panicle initiation

D. *Leaf area tiller^{-1} (cm^2) at physiological maturity*

Variation in leaf area tiller^{-1} of rice varieties (V) affected by various seedling age (SA) and transplanting density (SH) are given in Table 4. Analysis of the data indicated significant differences in leaf area in all the three varieties tested. The effect of varying seedling age and transplanting density significantly affected leaf area tiller^{-1}. Among the three varieties, greater leaf (121 cm^2) area was recorded in Fakhr e Malakand as compared to JP-5 and Swati-2014 (107 and 110 cm^2, respectively). Mean values of the data regarding seedling age indicated that higher leaf area (117 cm^2) were observed in 35 days old seedling which was similar with leaf area produced by 25 days old seedling (114 cm^2). The minimum leaf area (108 cm^2) tiller^{-1} was observed with 45 days old seedling. In case of transplanting density, transplanting at single seedling hill^{-1} produced more leaf area (121 cm^2) followed by 3 seedling hill^{-1} (112 cm^2). Minimum leaf area tiller^{-1} (106 cm^2) were recorded with transplanting 5 seedling hill^{-1}. The year effect was also found significant and greater leaf area tiller^{-1} was produced in 2019 as compared to 2018. The interaction V x SA indicated that increasing seedling age up to 35 days increased leaf area at maturity irrespective of varieties however, increasing seedling age beyond 35 days reduced leaf area in JP-5 and Fakhr e Malakand (Fig 6).

Table 4. Leaf area tiller^{-1} (cm^2) at physiological maturity of rice varieties as influenced by different seedling age and number of seedling hill^{-1}.

	Year		
Varieties (V)	2018	2019	Means
Fakhr e Malakand	110	132	121 a
JP-5	98	115	107 b
Swati-2014	102	119	110 b
LSD for V	6	7	5
Seedling Ages (SA)			
25 days	104	124	114 a
35 days	108	126	117 a
45 days	98	117	108 b
LSD for SA	6	7	5
Seedling Hill^{-1} (SH)			
1	111	130	121 a
3	102	121	112 b
5	96	116	106 c
LSD for SH	5	6	4
Year			
2018			103 b
2019			122 a
Significance			**

Interactions	Significance	Interactions	Significance
V x SA	**	V x SA x SH	ns
Y x V	ns	Y x SH	ns
Y x SA	ns	Y x V x SH	ns
Y x V x SA	ns	Y x SA x SH	ns
V x SH	ns	Y x V x SA x SH	ns
SA x SH	ns		

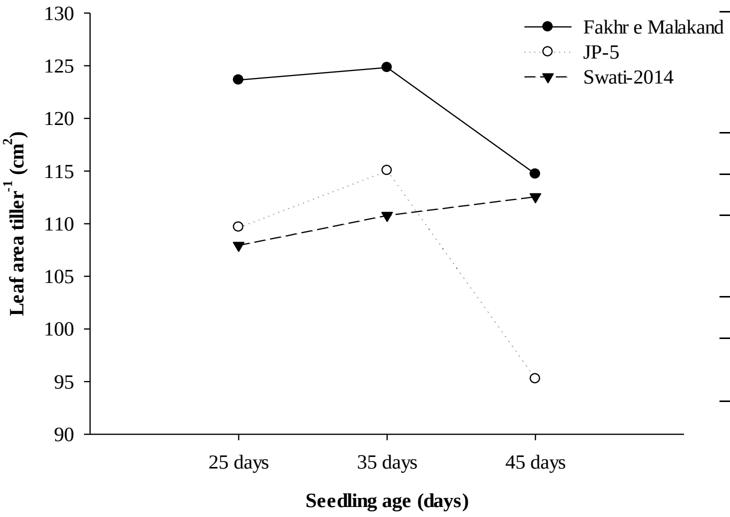

Fig. 6. Interaction V x SA for leaf area tiller^{-1} at physiological maturity

E. Leaf area index at 30 days after transplantation

Leaf area index (LAI) at 30 days after transplantation of rice varieties (V) as affected by different levels of seedling ages (SA) and seedling density hill^{-1} (SH) are presented in Table 5. Perusal of the data revealed that leaf area index at 30 days after transplantation was significantly different among the three varieties tested. Different seedling ages had no significant effect on LAI after 30 days of transpalantation. Seedling densities hill^{-1} significantly affected leaf area index at 30 days after transplantation. All the interactions were non-significant. Year as source of variation was also significant and LAI was higher in 2019 as compared to 2018. Fakhr e Malakand had higher leaf area index (1.25) at 30 days after transplantation, followed by Swati-2014 (1.16). The minimum leaf area index (1.02) was observed in JP-5. Increasing seedling density seedling hill^{-1} increased leaf area index. Higher leaf area index (1.21 and 1.19) was recorded by transplanting 5 and 3 seedling hill^{-1}, respectively. While lower leaf area index (1.03) was observed by transplanting single seedling hill^{-1}.

Table 5. Leaf area index at 30 days after transplantation of rice varieties as influenced by different seedling age and number of seedling hill^{-1}.

	Year		
Varieties (V)	2018	2019	Means
Fakhr e Malakand	1.20	1.29	1.25 a
JP-5	0.98	1.07	1.02 c
Swati-2014	1.09	1.24	1.16 b
LSD for V	0.11	0.11	0.08
Seedling Ages (SA)			
25 days	1.09	1.25	1.17
35 days	1.11	1.21	1.16
45 days	1.06	1.14	1.10
LSD for SA	NS	NS	NS
Seedling Hill^{-1} (SH)			
1	0.96	1.09	1.03 c
3	1.13	1.26	1.19 b
5	1.17	1.25	1.21 a
LSD for SH	0.06	0.08	0.05
Year			
2018			1.09 b
2019			1.20 a
Significance			**
Interactions	Significance	Interactions	Significance
V x SA	ns	V x SA x SH	ns
Y x V	ns	Y x SH	ns
Y x SA	ns	Y x V x SH	ns
Y x V x SA	ns	Y x SA x SH	ns
V x SH	ns	Y x V x SA x SH	ns
SA x SH	ns		

Table 6. Leaf area index at panicle initiation of rice varieties as influenced by different seedling age and number of seedling hill^{-1}.

	Year		
Varieties (V)	2018	2019	Means
Fakhr e Malakand	2.97	3.10	3.04 a
JP-5	2.36	2.64	2.50 c
Swati-2014	2.67	2.74	2.70 b
LSD for V	0.19	0.25	0.15
Seedling Ages (SA)			
25 days	2.80	2.90	2.85 a
35 days	2.65	2.93	2.79 a
45 days	2.54	2.65	2.59 b
LSD for SA	0.19	0.25	0.15
Seedling Hill^{-1} (SH)			
1	2.43	2.41	2.42 c
3	2.75	2.93	2.84 b
5	2.82	3.14	2.98 a
LSD for SH	0.15	0.19	0.12
Year			
2018			2.66 b
2019			2.83 a
Significance			*
Interactions	Significance	Interactions	Significance
V x SA	ns	V x SA x SH	ns

Y x V	ns	Y x SH	*
Y x SA	ns	Y x V x SH	ns
Y x V x SA	ns	Y x SA x SH	ns
V x SH	ns	Y x V x SA x SH	ns
SA x SH	ns		

F. *Leaf area index at panicle initiation*

Leaf area index at panicle initiation of different rice varieties (V) as influenced by various levels of seedling ages (SA) and seedling densities (SH) are presented in Table 6. Leaf area index of rice varieties at panicle initiation was significantly different. Different seedling ages and seedling densities considerably affected leaf area index at panicle initiation. The interactions effect were found non-significant. Leaf area index at panicle initiation was significantly different during the two years and greater leaf area index was recorded in 2019 as compared to 2018. Mean values of the data regarding varieties indicated greater leaf area index (3.04) of Fakhr e Malakand at panicle initiation, which was followed by Swati-2014 (2.7). JP-5 had the minimum leaf area index (2.5) at panicle initiation. Among different seedling ages, 25 days older seedling had higher leaf area index (2.85), which was similar with 35 days old seedling (2.79). Minimum leaf area index (2.59) at panicle initiation was observed with 45 days old seedling. In case of seedling density, transplanting 5 seedling hill^{-1} had greater leaf area index (2.98), followed by 3 seedlings hill^{-1} (2.84). Lower leaf area index (2.42) at panicle initiation was recorded with transplanting single seedlings hill^{-1}.

Table 7. Leaf area index at physiological maturity of rice varieties as influenced by different seedling age and number of seedling hill^{-1}.

	Year		
Varieties (V)	2018	2019	Means
Fakhr e Malakand	2.53	2.93	2.73 a
JP-5	2.11	2.47	2.29 c
Swati-2014	2.35	2.57	2.46 b
LSD for V	0.10	0.24	0.13
Seedling Ages (SA)			
25 days	2.47	2.73	2.60 a
35 days	2.32	2.76	2.54 a
45 days	2.19	2.48	2.33 b
LSD for SA	0.10	0.24	0.13
Seedling Hill^{-1} (SH)			
1	2.18	2.24	2.21 c
3	2.39	2.76	2.57 b
5	2.42	2.97	2.69 a
LSD for SH	0.11	0.19	0.11
Year			
2018			2.33 b
2019			2.66 a
Significance			*

Interactions	Significance	Interactions	Significance
V x SA	ns	V x SA x SH	ns
Y x V	ns	Y x SH	**
Y x SA	ns	Y x V x SH	ns
Y x V x SA	ns	Y x SA x SH	ns
V x SH	ns	Y x V x SA x SH	ns
SA x SH	ns		

G. *Leaf area index at physiological maturity*

Leaf area index at physiological maturity of rice varieties (V) as influenced by different seedling ages (SA) and number of seedling hill^{-1} (SH) are presented in Table 7. Analysis of data indicated that different varieties produced significantly different leaf area index at physiological maturity, similarly the effect of varying seedling age was also significant for leaf area index. Varying the number of seedlings hill^{-1} also significantly varied leaf area index. Mean values of the data shown that among three rice varieties, leaf area index at physiological maturity was higher (2.73) in Fakhr e Malakand, followed by Swati-2014 (2.46). However the minimum leaf area index (2.29) was noted with JP-5. In case of different seedling ages, greater leaf area index (2.60 and 2.54) at physiological maturity was calculated for seedling age of 25 and 35 days old, which were statistically similar with each other. Minimum leaf area index (2.33) was noticed with 45 days old seedling. Among different transplanting density hill^{-1}, transplanting 5 seedling hill^{-1} had greater leaf area index (2.69), which was followed by transplanting 3 seedlings hill^{-1} (2.57). Minimum leaf area index (2.21) at maturity was recorded with transplanting single seedling hill^{-1}. The year effect was also found significant and leaf area index was greater in 2019 as compared to 2018. The interaction effects were not significant.

Discussions

Plant height of different rice varieties was significantly different from each other. Taller plants were produced by JP-5 as compared to Fakhr e Malakand and Swati-2014. The variation in plant height of different varieties under same conditions might be due to the genetic variation in the varieties. Similar results were reported by Alam et al. (2009) who reported that different varieties produced variable plant height. Similarly Parashivamurthy et al. (2012) also reported that various genotypes were significantly different in growth characters like plant height. Among different seedling ages, plant height was higher with 35 days old seedling as compared to 25 and 45 days old seedling. The increase in plant height might be due to vigorous root growth and assimilates translocation to the upper part which leads to cell expansion and elongation, hence resulted in taller plants. Rahman et al. (2007) also reported taller plants in young seedling as compared to older seedling. Paramanik and Bera (2013) reported that plant height was considerably varied by seedling age. Likewise Vijayalaxmi et al. (2016) reported that plant height was significantly higher in 25-35 days old seedling at maturity stage.

Among transplanting densities, transplanting at single seedling hill^{-1} increased plant height and further increasing transplanting density decreased plant height. Which might be due to the competition among the seedlings for resources which resulted in short statured plant at higher transplanting densities. Our results are in line with Islam et al. (2008) who reported decreasing plant height with increasing number of seedling hill^{-1}. Similarly, Vijayalaxmi (2016) reported that plant height at single seedling hill^{-1} was the highest as compared to 5 seedlings hill^{-1}.

Leaf area and leaf area index of rice varieties were significantly different in various varieties. Leaf area and leaf area index of Fakhr e Malakand was higher than JP-5 and Swati-2014. The variation in leaf area and leaf area index among the varieties might be due to differences in tiller production, or leaf production which cover the canopy. Moreover, different seedling ages considerably affected leaf area and leaf area index of rice. Leaf area and leaf area index was higher with seedling age of 25 days seedling. The variation in leaf area and leaf area index of rice might be due to the faster activity of root and photosynthetic activity in younger seedling as compared to older seedling which resulted in more leaf area and leaf area index. Similar results were reported earlier by Rewainy et al. (2007) who reported higher leaf area and leaf area index in young seedlings as compared to older seedling. Likewise Vijayalaxmi et al. (2016) also reported higher leaf area index in 25 days old seedlings as compared to 15, 35 and 45 days old seedling. Li et al. (2020) reported that leaf area index decreased with increasing seedling age from 13 to 27 days old seedling. Leaf area index at heading stage decreased with increasing seedling age, which lead to reduction in dry matter accumulation (Ma et al., 2011). Seedling density hill^{-1} significantly affected leaf area and leaf area index of rice. Increasing seedling density increase leaf area index, while decreased leaf area. Higher leaf area was observed with single seedling hill^{-1} and higher leaf area index was observed with 5 seedling hill^{-1}. The increased leaf area and leaf area index with higher density might be due to more canopy occupation at higher density or higher number of tiller production. Hasanuzzaman et al. (2009) reported that leaf area index was lower at lower transplanting density due to production of low tiller number at low density hill^{-1}. Similarly Vijayalaxmi et al. (2016) reported that leaf area index was higher at 5 seedling hill^{-1} as compared to 1 and 3 seedling hill^{-1}.

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