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Assessment of phyllochron and tillers contribution to grain yield of rice

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ABSTRACT

Field experiments were carried out at Tamil Nadu Agricultural University, Coimbatore, India during samba (August-December) season of 2012 and 2013 to address the contribution of phyllochron and main culm, primary, secondary and tertiary panicles to grain yield of low land rice with the objective of to investigate the tillering and grain production in main culm, primary, secondary and tertiary tillers due to varied crop geometry, age and number of seedlings in rice. The experiment consisted of three main-plot treatments and replicated thrice in a split plot design. Crop geometry of 25 x 25 cm in association with 14 DOS with one seedling hill^{-1} resulted higher panicle weight (5.35, 4.16, 3.55 and 2.90 g) on main culm, primary, secondary and tertiary panicles, respectively compared to all other combinations. Combination of transplanting of rice at wider spacing of 25 x 25 cm and 14 DOS with one seedling hill^{-1} was found to record higher grain yield (7303 kg ha^{-1}) than other treatments.

Key words: *Main culm, rice-phyllochron, primary-secondary-tertiary panicles, yield*

INTRODUCTION

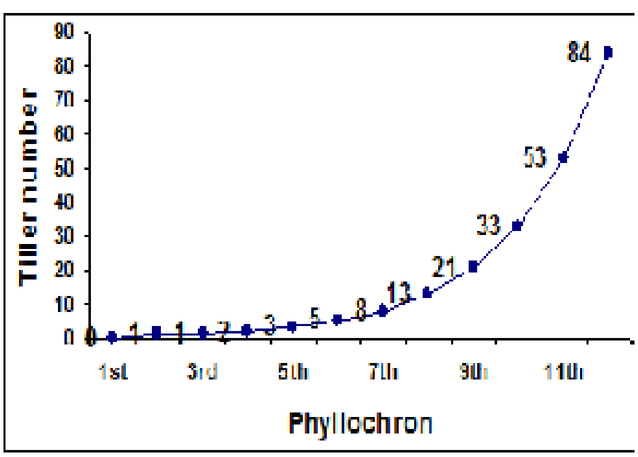
Two decades ago, a System of Rice Intensification (SRI), based on some new insights into how rice can be grown best, translated into certain principles and practices, was developed in Madagascar. It has helped farmers increase their grain yield from 2 to 8 tons ha^{-1} or more by changing plant, soil, water and nutrient practices such as planting very young seedlings, wide spacing, mechanical control of weeds, and use of compost with limited use of chemical fertilizers. The system recognizes the rice as having great unattained internal potential for tillering and seeks to provide an optimum environment in order to allow the plant to manifest such potential. Before proceeding any further, the term phyllochron needs to be introduced since it will be used very often in this paper. Phyllochron, which has been used to characterize the growth dynamics of cereals, is defined as the interval of leaf emergence. It varies in a function of temperature, day length, nutrition, light intensity, planting density and humidity (Nemoto et al., 1995). The modeling of the phyllochron was first published in 1951 when Katayama presented the growth rules he had worked out for leaf emergence on the main stem and tillers of rice, wheat and barley. The numbers of tillers that emerged from the main tiller and subsequent tillers according to respective tiller orders (main, primary, secondary, tertiary) reflecting their sequence of emergences. The number of total tillers and tertiary tillers increased ex-potentially as the number of phyllochrons (often referred to as leaf number) advanced. It was the growth in number of tertiary tillers that drove the total number up so sharply.

The number of primary and secondary tillers increased more linearly with the advance of phyllochrons (the number of periods of tiller emergence). The first primary tiller emerges from the main tiller in the fourth phyllochron, with additional primary tillers up to six in the next five phyllochron periods. The first secondary tiller comes out later, from the base of the first primary tiller, in the seventh phyllochron, while the first tertiary tiller emerges from the base of the first secondary tiller in the tenth phyllochron.

Phyllochrons are a regular interval or period of plant growth observable for all gramineae species. These 'growth cycles' can be as short as 5 days (under ideal growth conditions) or up to 10 days (with less favorable conditions). During each phyllochron beyond the third, one or more phytomers (a unit of tiller, leaf and root) are produced from the plant's apical meristematic tissue. They are particularly important for rice, which is a potentially high-tillering plant provided that its root system is intact and the root system and canopy are not constrained by crowding. Between 6 and 12 phyllochrons may be completed before panicle initiation, when vegetative growth stops and the plant goes into its reproductive phase. The most detailed discussion of phyllochrons in rice in English language is by Nemoto et al. (1995) though they were first identified and analyzed by a Japanese researcher, T. Katayama, about 75 years ago.

The detailed work on phyllochrons by Fr. de Laulanié (1993), who developed SRI, found somewhat different numbers. He agrees that the first primary tiller emerges in the 4th phyllochron, but according to his observations, the first secondary tiller emerges in the 6th phyllochron, and the first tertiary tiller in the 8th phyllochron. A total of 84 tillers should be possible by the end of the 11th phyllochron according to Laulanié's calculations (a) if that many could be completed before panicle initiation, (b) if the plant has not lost much of its root system due to hypoxia and (c) if its root and tiller growth is not constrained by close planting.

The distribution of different types of tillers at the various phyllochron stages is indicated.



The percentage of primary tillers among total tillers decreased with the increase of phyllochron. The peak percentage of secondary tillers occurs in the tenth phyllochron; after that, the percentage decreases slowly. The percentage of tertiary tillers increases from the ninth phyllochron by about 5% in the increase of each phyllochron. Therefore, after the ninth phyllochron, the percentage of tertiary and secondary tillers among total tillers increases. Theoretically, with the advance of phyllochrons, especially after the ninth period, small and late emergent tillers will occupy a large portion of the total number of tillers in the rice plant. Reasonable tiller number should be a consideration in assessing the components of panicle performance for high yielding cultivation of rice. Keeping this point in view, the present investigations was undertaken with objective of to investigate the tillering and grain production in main culm, primary, secondary and tertiary tillers due to varied crop geometry, age and number of seedlings in rice.

MATERIALS AND METHODS

Field experiments were carried out at Tamil Nadu Agricultural University, Coimbatore, India during samba (August-December) season of 2012 and 2013. Coimbatore is situated in the Western agro-climatic zone of Tamil Nadu at 11°N latitude and 77°E longitude and at an altitude of 426.7 m above mean sea level. The soil of the experimental field was clay loam in texture belonging to Typic Haplustalf with low in available N (199.0 and 207.5 19 kg ha^{-1}), low in available P (9.0 and 11.0 kg ha^{-1}) and high in available K (419.0 and 426.7 kg 20 ha^{-1}) during the first and second years respectively. The experiments consisted of three main-plot treatments *viz.,* M_1 - 25 x 25 cm, M_2 - 25 x 20 cm and M_3 - 25 x 15 cm and six sub-plot treatments, S_1 - 14 Day Old Seedlings (DOS) + 1 seedling hill^{-1}, S_2 - 14 DOS + 2 seedlings hill^{-1}, S_3 - 14 DOS + 3 seedlings hill^{-1}, S_4 - 21 DOS + 1 seedling hill^{-1}, S_5 - 21 DOS + 2 seedlings hill^{-1} and S_6 - 21 DOS + 3 seedlings hill^{-1}. The treatments are replicated thrice in a split-plot design; the rice variety CO (R) 50 with field duration of 135 days was used in the trial. Separate nurseries were raised for conventional and SRI method of planting to transplant 21 and 14 DOS, respectively. All other package of practices were carried out as per recommendation of CPG (2012).

Phyllochron observation

Phyllochron is defined as time interval between appearance of successive leaves on a culm (days leaf^{-1}) (Wilhelm and Mc Master, 1995). Five plants were marked in each plot and emergence of successive leaf on the culm was recorded by placing small rubber band around the leaf tip. The phyllochron observation was taken on every alternate day.

Panicle weight

Five plants of main culm, primary, secondary and tertiary panicles were collected and weighed using an electronic balance. The mean weight of the panicle was calculated and expressed in g.

Number of panicles

In each plot, five plants were tagged at random and fixed for observation after harvesting. In the tagged plant, the number of panicle m^{-2} in main culm, primary, secondary and tertiary panicles was calculated by multiplying the number of main culm, primary, secondary and tertiary panicle hill^{-1}, respectively with plant population m^{-2}. From the main culm, primary, secondary and tertiary panicles m^{-2}, total number of panicles m^{-2} was obtained.

Grain yield

Grains from each net plot were cleaned, sun dried, weighed and adjusted to 14 per cent moisture content and the grain yield was expressed as kg ha^{-1}.

Straw yield

The straw obtained from each net plot area was sun dried and weighed. The straw yield was expressed as kg ha^{-1}.

RESULT AND DISCUSSION

Two set of treatments *viz.*, crop geometry, age and number of seedlings in the investigations were represented as M and S, respectively. The levels of crop geometry followed were expressed as M_1, M_2 and M_3; and the age and number of seedlings approaches adopted in the study were denoted as S_1, S_2, S_3, S_4, S_5 and S_6 accordingly for easy interpretation of results obtained.

During the development of each phyllochron, it was an increasing trend from 3rd leaf to the last leaf of inception.

The pooled two seasons' data on crop geometry had significant effect on phyllochron at 8th, 9th, 10th and 11th phyllochron. Rice planted at 25 x 15 cm spacing (M_3) took more time (5.5 days) to put-forth of new leaf and was on par with M_2 (25 x 20 cm) compared to M_1 (25 x 25 cm spacing) at 8th phyllochron (Fig. 1). Similar trend was noted between 9th, 10th and 11th phyllochron.

Age and number of seedlings had significant effect on phyllochron at 4th, 8th, 9th, 10th and 11th phyllochron in both the years. Transplanting on 21 DOS with one seedling hill^{-1} (S_4) took more time (6.6 days) to put-forth of new leaf and was on par with S_5 (21 DOS with two seedlings hill^{-1}) and S_6 (21 DOS with three seedlings hill^{-1}) compared to others at 4th phyllochron. At 8th phyllochron S_6 (21 DOS with three seedlings hill^{-1}) had taken maximum time (5.5 days) and it was comparable with S5 (21 DOS with two seedlings hill^{-1}) and S_3 (14 DOS with three seedlings hill^{-1}). Almost same trend was noted on 9th, 10th and 11th phyllochron (Fig. 2).

Interaction between crop geometry, age and number of seedlings on phyllochron of each leaf production in both the years was non significant.

Yoshida (1981) reported that early to medium duration rice cultivars produce 10 to 18 leaves on the main culm. Similar result was found in this study where medium duration rice cultivar Co (R) 50 produced 14-15 leaves on main culm. Plant density is one of the

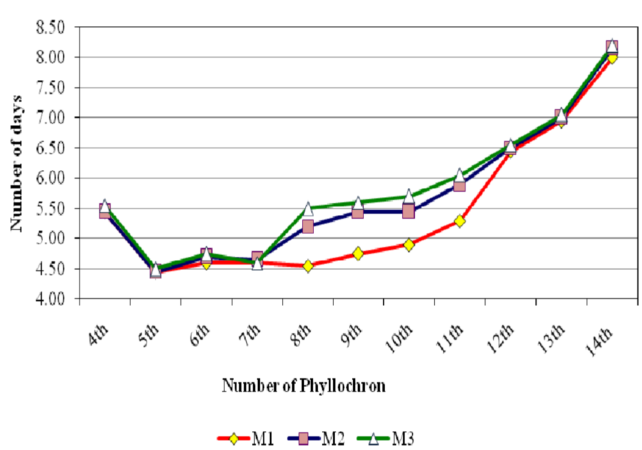


Fig. 1. Influence of crop geometry on phyllochron of rice.

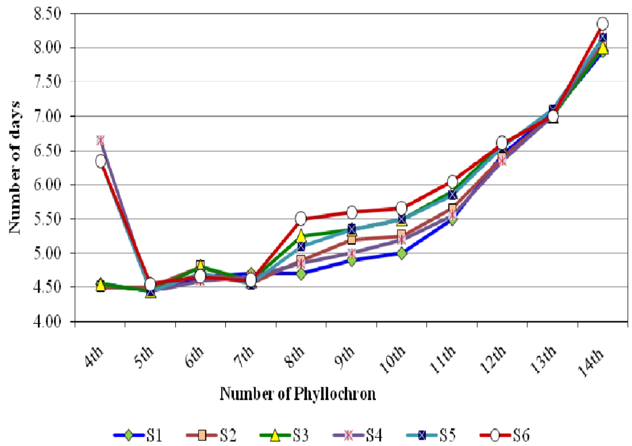


Fig. 2. Influence of age and number of seedlings on phyllochron of rice.

main factors that determine the leaf appearance rate. The observation indicated that higher the density (due to closer spacing), slower was the rate of appearance. This result is in accordance with findings of Baskar (2009).

Age and number of seedlings had significant effect on phyllochron. In general, transplanting of 14 day old at any number of seedlings hill^{-1} (one or two or three) took lesser time to put-forth phyllochron (4th phyllochron) compared to others. Also, younger (14 DOS) seedlings with either one or two seedlings hill^{-1} or aged (21 DOS) seedlings with either one seedling hill^{-1} (8th phyllochron) took lesser number of days to produce phyllochron than others. This might be due to young seedlings have minimum transplanting shock compared to older seedlings and lesser number of seedlings (one or two) might have led lesser competition for light and nutrients in turn induced better growth and development of rice and quick emergence of phyllochron. Similar results were observed by Sarwar (2011).

The pooled two seasons' data on panicle weight (g) (Table 1) values indicated that rice transplanted at 25 x 25 cm recorded comparatively higher main culm, primary, secondary and tertiary panicles weight (4.86, 3.66, 3.28 and 2.53 g panicle^{-1}), respectively and was on par with 25 x 20 cm on primary and tertiary panicles weight. Minimum panicles weight (4.28, 3.37, 2.93 and 2.10 g panicle^{-1}) was noticed in 25 x 15 cm on main culm, primary, secondary and tertiary panicles, respectively. Among the age and number of seedlings, 21 DOS with two seedlings hill^{-1} attained its statistical supremacy by producing higher panicle weight (4.91 g) on main culm than others and it was on par with 14 DOS with one seedling hill^{-1}. Obviously, the lowest panicles weight (4.33 g panicle^{-1}) was observed with 21 DOS with three seedlings hill^{-1}. The same trend was noticed with primary, secondary and tertiary panicles weight.

The interaction effect of two seasons' pooled analysis data showed that between crop geometry, age and number of seedlings was found to be significant. Crop geometry of 25 x 25 cm in association with 14 DOS with one seedling hill^{-1} resulted higher panicle weight (5.35, 4.16, 3.55 and 2.90 g) on main culm, primary, secondary and tertiary panicles, respectively compared to all other combinations. The minimum panicle weight (3.81, 2.96, 2.49 and 1.76 g) was recorded in 25 x 15 cm spacing and 21 DOS with three

Table 1. Influence of phyllochron and tillers contribution on panicle weight (g) of rice (Pooled analysis data)

Treatments	Main culm panicle				Primary panicle				Secondary panicle				Tertiary panicle			
	M_1	M_2	M_3	**Mean**	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean
S_1	5.35	4.58	4.16	**4.70**	4.16	3.85	3.67	**3.89**	3.55	3.41	3.35	**3.43**	2.90	2.67	2.49	**2.68**
S_2	4.76	4.41	4.28	**4.48**	3.54	3.50	3.25	**3.43**	3.25	3.02	2.72	**3.00**	2.70	2.28	2.35	**2.44**
S_3	4.88	4.53	4.26	**4.56**	3.33	3.53	3.25	**3.37**	3.19	2.97	2.59	**2.92**	2.39	2.47	2.01	**2.26**
S_4	4.47	4.51	4.48	**4.49**	3.79	3.10	3.30	**3.40**	3.39	2.80	3.00	**3.06**	2.52	2.43	2.06	**2.37**
S_5	5.07	4.95	4.70	**4.91**	3.66	3.79	3.83	**3.76**	3.31	3.03	3.43	**3.26**	2.32	2.58	1.92	**2.27**
S_6	4.64	4.53	3.81	**4.33**	3.46	3.31	2.96	**3.24**	2.95	3.07	2.49	**2.84**	2.38	2.21	1.76	**2.12**
Mean	**4.86**	**4.58**	**4.28**		**3.66**	**3.51**	**3.37**		**3.28**	**3.05**	**2.93**		**2.53**	**2.44**	**2.10**	
	M	**S**	**M at S**	**S at M**	**M**	**S**	**M at S**	**S at M**	**M**	**S**	**M at S**	**S at M**	**M**	**S**	**M at S**	**S at M**
SEd	0.10	0.12	0.21	0.21	0.07	0.11	0.19	0.19	0.07	0.09	0.16	0.15	0.05	0.06	0.11	0.10
CD(P=0.05)	0.27	0.24	0.46	0.41	0.20	0.23	0.40	0.39	0.20	0.17	0.34	0.30	0.15	0.12	0.24	0.21

M_1 - 25 x 25 cm, M_2 - 25 x 20 cm, M_3 - 25 x 15 cm, S_1 - 14 DOS + one seedling hill^{-1}, S_2 - 14 DOS + two seedlings hill^{-1}, S_3 - 14 DOS + three seedlings hill^{-1}, S_4 - 21 DOS + one seedling hill^{-1}, S_5 - 21 DOS + two seedlings hill^{-1}, S_6 - 21 DOS + three seedlings hill^{-1}

Table 2. Influence of phyllochron and tillers contribution on number of panicles (m $^{-2}$) of rice (Pooled analysis data)

Treatments	Main culm panicles				Primary panicles				Secondary panicles				Tertiary panicles			
	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean
S_1	16.0	20.0	27.0	**21.0**	62.8	67.9	78.1	**69.6**	129.7	138.2	151.6	**139.8**	101.0	89.2	78.5	**89.6**
S_2	32.0	40.0	54.0	**42.0**	51.0	57.4	66.1	**58.2**	106.3	117.3	127.7	**117.1**	91.9	75.6	66.2	**77.9**
S_3	48.0	60.0	81.0	**63.0**	46.5	52.3	62.5	**53.8**	97.3	107.1	120.6	**108.3**	87.4	68.9	57.4	**71.3**
S_4	16.1	20.0	27.0	**21.0**	53.7	58.6	70.5	**60.9**	111.7	119.5	136.6	**122.6**	95.7	77.1	66.8	**79.8**
S_5	32.0	40.0	54.0	**42.0**	53.5	61.1	73.3	**62.7**	111.3	124.7	142.1	**126.0**	93.7	80.4	63.6	**79.2**
S_6	48.0	60.0	81.0	**63.0**	42.1	50.5	62.1	**51.6**	88.6	103.4	119.8	**103.9**	85.2	66.6	51.7	**67.9**
Mean	**32.0**	**40.0**	**54.0**		**51.6**	**58.0**	**68.8**		**107.4**	**118.4**	**133.0**		**92.5**	**76.3**	**64.0**	
	M	S	M at S	S at M	M	S	M at S	S at M	M	S	M at S	S at M	M	S	M at S	S at M
SEd	0.02	0.03	0.04	0.04	1.3	1.5	2.65	2.55	2.55	3	5.45	5.25	1.7	2.05	3.65	3.5
CD (P=0.05)	0.05	0.05	0.1	0.09	3.6	3	NS	NS	7.05	6.15	NS	NS	4.65	4.15	NS	NS

M_1 - 25 x 25 cm, M_2 - 25 x 20 cm, M_3 - 25 x 15 cm, S_1 - 14 DOS + one seedling hill^{-1}, S_2 - 14 DOS + two seedlings hill^{-1}, S_3 - 14 DOS + three seedlings hill^{-1}, S_4 - 21 DOS + one seedling hill^{-1}, S_5 - 21 DOS + two seedlings hill^{-1}, S_6 - 21 DOS + three seedlings hill^{-1}

seedlings hill^{-1} on main culm, primary, secondary and tertiary panicles, respectively.

The panicle weight was significantly influenced by the crop geometry levels. Wider spacing of 25 x 25 cm produced higher panicle weight of main culm, primary, secondary and tertiary panicles than other spacing levels. Presence of wider spacing between plants might have provided better soil resources such as water, nutrients in addition to better above ground resources (air and sunlight). This might have been the reason for better growth and physiological characters which ultimately provided more panicles weight. The results are in agreement with the findings of Borkar et al. (2007). Twenty one day old two seedlings hill^{-1} or 14 day old one seedling hill^{-1} produced higher panicle weight on main culm, primary, secondary and tertiary panicles than others. It might be due to more amount of light interception, chlorophyll content and higher amount of nutrient uptake resulted in better panicle weight. Nayak et al. (2003) also corroborated the findings.

Crop geometry, age and number of seedlings of rice had a marked influence on number of panicles m^{-2} of two season pooled analysis (Table 2).

Rice transplanted under 25 x 15 cm (M_3) recorded significantly more number of main culm, primary and secondary panicles (54.0, 68.8, 133.0 m^{-2}, respectively) than M_1 and M_2. Whereas, tertiary panicles were recorded the highest (92.5 m^{-2}) at spacing of 25 x 25 cm (M_1) over others. Crop geometry of 25 x 25 cm (M_1) resulted in perceptibly fewer main culm, primary and secondary panicles (32.0, 51.6 and 107.4 m^{-2}, respectively) than others. The lowest tertiary panicles (64.0 m^{-2}) were recorded with M_3.

Significantly higher number of main culm panicles (63.0 m^{-2}) was registered with 21 DOS with three seedlings hill^{-1} (S_6) than others and was comparable with S_3 (14 DOS with three seedlings hill^{-1}). The treatment S_1 (14 DOS with one seedling hill^{-1}) was found to be inferior in registering the least number of main culm panicles m^{-2} (21.0 m^{-2}). However, maximum number of primary panicles (69.6 m^{-2}) was recorded with S1 (14 DOS with one seedling hill^{-1}). The least number of primary panicles (51.6 m^{-2}) was registered with 21 DOS with three seedlings hill^{-1} (S6). Same trend was noted with secondary and tertiary panicles too.

None of the treatment combinations *viz.,* crop geometry, age and number of seedlings of rice did influence on number of panicles m-2 in any of years.

Wider spacing of 25 x 25 cm resulted in higher number of panicles m^{-2} on primary, secondary and tertiary panicles over others. It might be attributed to reduced above and below ground competition, greater root and shoot development, resulting in improved number of panicles m^{-2}. This result is in confirmity with the findings of Sridevi and Chellamuthu (2007).

Higher number of panicles m^{-2} (primary, secondary and tertiary panicles) was registered under planting of young seedling with one seedling hill^{-1}. Transplanting of younger seedling had higher tillering capacity, more time for producing tillers and better conversion efficiency of tillers to productive tillers otherwise higher number of panicles unit area^{-1}. The

Table 3. Influence of phyllochron and tillers contribution on grain and straw yield of rice (Pooled analysis data).

Treatments	Grain yield (kg ha^{-1})			
	M_1	M_2	M_3	Mean
S_1	7303	6726	6073	**6701**
S_2	6111	5984	5823	**5973**
S_3	6345	5651	5565	**5854**
S_4	6285	5941	5653	**5960**
S_5	6425	7144	6954	**6841**
S_6	5014	5470	6063	**5516**
Mean	**6247**	**6153**	**6022**	
	M	S	M at S	S at M
SEd	156	192	341	332
CD (P=0.05)	NS	391	749	678

M_1 - 25 x 25 cm, M_2 - 25 x 20 cm, M_3 - 25 x 15 cm, S_1 - 14 DOS + one seedling hill^{-1}, S_2 - 14 DOS + two seedlings hill^{-1}, S_3 - 14 DOS + three seedlings hill^{-1}, S_4 - 21 DOS + one seedling hill^{-1}, S_5 - 21 DOS + two seedlings hill^{-1}, S_6 - 21 DOS + three seedlings hill^{-1}

present findings are in confirmity with result of Thiyagarajan et al. (2002).

The assessment of any treatment effect should ultimately help to arrive the economic yield. In cereal crops like rice, both grain and straw are the valuable economic parts. Whenever, the basic objectives proposed for any experiment in Agronomy, the final consideration vests on the treatmental effect on yield attributes and its influence on the ultimate economic yield.

Discernible variations have been observed due to age and number of seedlings during field experiments (Table 3). Among the different age and number of seedlings treatments, transplanting of 21 DOS with two seedlings hill^{-1} resulted in higher grain yield (6841 kg ha^{-1}) on during experiments. It was on par with 14 DOS with one seedling hill-1 and was superior over others. The lowest grain yields (5516 kg ha^{-1}) were recorded due to transplanting of 21 DOS with three seedlings hill^{-1}.

The interaction effect observed between crop geometry, age and number of seedlings was significant. Combination of transplanting of rice at wider spacing of 25 x 25 cm and 14 DOS with one seedling hill^{-1} was found to record higher grain yield (7303 kg ha^{-1}) than other treatments and was statistically comparable with 25 x 20 cm and 21 DOS with two seedlings hill^{-1}, 25 x 15 cm spacing along with 21 DOS with three seedlings hill^{-1} and 25 x 20 cm and 14 DOS with one seedling hill^{-1}. The lowest grain yield (5014 kg ha^{-1}) was recorded in 25 x 25 cm spacing and 21 DOS with three seedlings hill-1 during experimentation.

Combination of wider spacing (25 x 25 cm) with young (14 DOS) and one seedling hill^{-1} produced higher grain yield of rice compared to others. The increased grain yield was due to increase in almost all growth and yield attributing traits and better nutrient uptake. Regression analysis also indicated positive response on yield of rice by secondary panicle weight (g) and filled grains panicle^{-1}. Efficient utilization of resources and less inter and intra space competition among widely spaced plants which may be assigned as the reason for superiority in these yield attributes of rice and consequently increased yield. Wider spacing provided a situation where there was decreased intra-plant competition for resources (Sharratt and Mc Williams, 2005). Wider spacing created conducive condition for un-inhibited root and shoot growth that would have ensured better access to light and air thereby created better environment to produce higher yield attributes and in turn higher grain yield of rice. This observation is similar to Satyanarayana et al. (2007). Transplanting of younger (14 DOS) and one seedling had higher tillering capacity and more vigour which helped in extracting nutrients from soil and in turn influencing yield. Similar findings were reported by Thiyagarajan and Gujja (2013). More number of tillers unit area^{-1} and better conversion of productive tillers unit area^{-1} ultimately produced higher grain yield. The production of higher LAI, better light interception and more DMP influenced shoot: root ratio thereby increased the tiller production and number of main culm panicles and nutrient uptake favourably, hence increased grain yield. Closer spacing intercepted maximum photosinthetically active radiation (PAR) which in turn lead to higher DMP and much of assimilates translocated for grain filling came from current photosynthesis than wider spacing. Similar findings were reported by Rasool et al. (2013).

CONCLUSION

The spacing level becomes closer (*i.e.,* 25 x 20 cm), young (14 DOS) and one seedling hill^{-1} or old (21 DOS) and two seedlings hill^{-1} were failed to perform due to poor conversion efficiency of tillers into productive tillers and panicle weight. To compensate the losses of yield attributes, both age and number of seedlings hill^{-1} are to be increased. Presence of more phyllochron in aged seedlings and more number of seedlings hill^{-1} put-forth the tillers quickly and enhanced the number of tillers m^{-2} at early stages. Whereas, when the stage advances, due to the greater ability of younger and one seedling hill^{-1} produced more number of tillers hill^{-1} and in turn number of tillers m^{-2} than other older seedlings. Hence, when the spacing becomes closer (25 x 15 cm), 21 day old two seedlings hill^{-1} performed equally to the 25 x 25 cm spacing in association of 14 day old one seedling hill^{-1}. From this study, it can be concluded that planting 14 day old seedlings with one seedling hill^{-1} at a spacing of either 25 x 25 cm or 25 x 20 cm; or 21 day old seedlings with two seedlings hill^{-1} at either 25 x 15 cm or 25 x 20 cm spacing was found to be optimum for enhancing rice production in Western agro-climatic zone of Tamil Nadu.

REFERENCES

Baskar P (2009). Standardisaton of nursery techniques and crop geometry for rice under System of Rice Intensification (SRI). M.Sc. (Ag.) Thesis, Tamil Nadu Agric. Univ., Coimbatore, Tamil Nadu, India

Borkar LS, Khawale VS, Raut PB, Patil TS and Kolte HS (2008). Studies on spacing and nitrogen management under System of Rice Intensification (SRI). J. Soil Crops 18(2): 438-441

Nayak BC, Dalei BB and Chodhury BK (2003). Response of hybrid rice to date of planting, spacing and seedling rate during wet season. Indian J. Agron.48(3): 172-174

Nemoto K, Morita S and Baba T (1995). Shoot and root development in rice related to the phyllochron. Crop Science 35(1): 24-29

Rasool F, Habib R and Bhat MI (2016). Agronomic evaluation of rice (*Oryza sativa* L.) for plant spacings and seedlings hill-1 under temperate conditions. African J. Agric. Res.8(37): 4650-4653

Sarwar N, Maqsood M, Wajid SA and Anwar-ul-Haq M (2011). Impact of nursery seeding density, nitrogen and seedling age on yield and yield attributes of fine rice. Chilean J. Agric. Res. 71(3):343-349

Satyanarayana A, Thiyagarajan TM and Uphoff N (2007). Opportunities for water saving with higher yield from the system of rice intensification. Irrigation Science.25: 99-115

Sharratt BS and Mc Williams DA (2005). Microclimatic and rooting characteristics of narrow row versus conventional row corn. Agronomy. J. 97: 1129-1135

Sridevi V and Chellamuthu V (2007). Effect of System of Rice Intensification (SRI) practices on the yield and yield attributes of rice. In: Extended summaries of 2nd Nat. Sym. on System of Rice Intensification in India-progress and prospects. Oct. 3rd-5th. Agartala, Tripura. pp. 74

Thiyagarajan TM and Gujja B (2013). Transforming Rice Production with SRI (System of Rice Intensification) Knowledge and Practice. National Consortium on SRI (NCS)

Thiyagarajan TM, Velu V, Ramasamy S, Durgadevi D, Govindrajan D, Priyadarshini R, Sudhalakshmi C, Senthilkumar K, Nisha PT, Gayathry G, Hengsdijk H and Bindraban PS (2002). Effect of SRI practices on hybrid rice performance in Tamil Nadu, India. In: Water wise rice production (ed). B.A.M. Bouman, H. Hengsdijk, B. Hardy, P.S. Bindraban, T.P. Towng and J. K. Zadha. IRRI Publication, The Philippines. pp. 119-127

Yoshida S (1981). Fundamentals of rice crop science. IRRI. Los Banos, The Philippines