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Influence of Crop Establishment Methods and Weed Management Practices on Nutrient Uptake of Transplanted Rice

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Field experiments were conducted in clay loam soil in the wet land farm of Tamil Nadu Agricultural University, Coimbatore during *rabi,* 2011-12 and 2012-13 to evaluate the different crop establishment methods and weed management practices in lowland transplanted rice. The experiments were laid out in strip plot design with three replications. The treatments consisted of three crop establishment methods as horizontal strips and six weed management practices as vertical strips. The results of the study revealed that mechanical transplanting (30 x 20 cm) with conoweeding four times at 10 days interval, starting from 10 DAT had recorded better root characteristics such as root length, volume and dry weight attributing to higher nutrient uptake by rice resulting in higher grain and straw yield. This practice was comparable with mechanical transplanting (30 x 20 cm) with preemergence application of pretilachlor @ 0.75kg a.i. ha^{-1} + early post emergence of bispyribac sodium @ 20g a.i. ha^{-1} + conoweeding at 40 DAT.

Key words: Machine planting, Nutrient uptake, Root dry weight, Grain and straw yield

Rice is a staple food crop of India, providing 43 per cent of calorific requirement for more than 70 per cent of the population. The area of rice grown in India (44 million ha) is the largest among all rice growing countries of the world with an annual production of around 89 million tonnes. To meet out the growing demands the present production level needs to be enhanced to 120 million tonnes by 2020. This estimated increase is to be achieved in the backdrop of declining and deteriorating resource base such as land, water, labour and inputs, without adversely affecting the quality of environment (Viraktamath *et al*., 2006). The System of Rice Intensification (SRI) has its own methodologies *viz.,* transplanting of young seedlings usually 8-12 days old, transplanting single seedling per hill at wider spacing in a square geometry, use of mechanical weeder permitting greater root growth and tillering, and provides other favorable conditions for better growth (Kumar and Shivay, 2004). Transplanting and weed management require more labour in SRI when compared to traditional practices. These operations are spread over a couple of weeks in a production season, causing labour scarcity in rice growing areas. The scarcity causes delay in agricultural operations, which in turn affects crop productivity. Due to high labour cost, profit from SRI cultivation is marginal. However, SRI the mechanization to reduce the cost of planting and weeding has potential to reduce the cost of rice cultivation substantially (Mohapatra *et al.,* 2012). But, the crop is subjected to greater weed competition for various resources, *viz.,* nutrients, light and space than transplanted rice, because both the crop and weed seeds emerge at the same time resulting in reduced crop yield by 50–100 per cent.

Therefore, control of weeds is important to maximize the utilization of inputs in order to increase the productivity. Herbicides are promising and viable option than other methods, because of their quick performance in decreasing weeds competition, easy to use, low cost and less labour. Hence, agronomical manipulations such as crop establishment methods with appropriate weed management practices may offer an effective option enhancing rice yield. In cognizance of the above facts, the present study was undertaken.

Materials and Methods

Field experiments were conducted during r*abi* 2011-12 and 2012-13 at wetland farm of Tamil Nadu Agricultural University, Coimbatore situated at 11ÚN latitude, 77ÚE longitude at an altitude of 426.7 m above mean sea level, to examine the performance of rice under various crop establishment methods and weed management practices. The soil of the experimental field was clay loam in texture, low in available nitrogen, medium in available phosphorus and high in available potassium. The treatments were replicated thrice in strip plot design with three crop establishment techniques *viz.,* conventional planting (C_1), SRI marker planting (C_2) and SRI machine planting (C_3) assigned to horizontal strips and six weed management practices *viz.,* conoweeding at 10, 20, 30 and 40 DAT (W_1), pre

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emergence (PE) Pretilachlor 50% EC @ 0.75kg a.i. ha^{-1} + conoweeding at 20 and 40 DAT (W_2), PE Pretilachlor 50% EC @ 0.75kg a.i. ha^{-1} + early post emergence (EPOE) Bispyribac sodium 10% SC @ 20g a.i. ha^{-1} (W_3), PE Pretilachlor 50% EC @ 0.75kg a.i. ha^{-1} + EPOE Bispyribac sodium 10% SC @ 20g a.i. ha^{-1} + conoweeding at 40 DAT (W_4), EPOE Laundax power @ 10 kg ha^{-1} + conoweeding at 30 and 40 DAT (W_5) and un-weeded control (W_6) allotted to vertical strips. The variety CO (R) 49 was used in the trials.

SRI machine planting and marker planting involved 12 days old single seedling $hill^{-1}$ at 30 x 20 cm and 25 x 25cm spacing, respectively in comparison to conventional transplanting (CT) of 21 days old 2-3 seedlings $hill^{-1}$ at 20 cm x 10 cm spacing. The seed requirement in SRI marker and machine planting was 8 kg ha^{-1} and 10 kg ha^{-1}, respectively, while it was 40 kg ha^{-1} in planting Raised bed nursery for SRI planting (Baskar, 2009), tray type nursery for SRI mechanical transplanting (Bell *et al.,* 2003) and conventional nursery for conventional transplanting (CPG, 2005) were prepared and used.

Five hills from each replication were randomly selected and root samples were collected by removing a cylinder of soil along with the hill by using an auger (10 cm in diameter and 45 cm depth) as suggested by Kawata and Katano (1976). Roots were carefully washed and their length and dry weight were measured. Root volume was measured by water displacement method by putting all roots in a measuring cylinder. Grains and straw were sun dried to 14 per cent moisture and the weight was recorded for each plot and computed per hectare basis.

Results and Discussion

Root characteristics

Crop establishment methods and weed management practices had significant influence on root characteristics on 40 DAT during both the years of experimentation (Table 1). Among the crop establishment methods, mechanical transplanting (C_3) recorded significantly higher root dry weight than conventional transplanting (C_1). However, it was comparable with SRI marker planting (C_2) during both the years. SRI plants supported by intermittent

Table 1. Effect of crop establishment methods and weed management practices on root characteristics in rice

Treatment	Root volume (cc $hill^{-1}$)							
	2011-12				2012-13			
	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean
W_1	23.7	28.7	32.2	28.2	19.9	25.3	30.7	25.3
W_2	17.2	24.3	26.3	22.6	13.5	21.2	24.2	19.6
W_3	20.5	26.0	29.0	25.2	17.4	24.4	26.8	22.9
W_4	21.7	26.9	31.1	26.5	19.1	26.5	30.1	25.2
W_5	19.8	25.9	27.3	24.3	16.9	22.8	25.3	21.7
W_6	10.5	13.8	16.4	13.6	10.7	12.3	14.6	12.5
Mean	18.9	24.3	27.1		16.2	22.1	25.3	
	W	C	C at W	W at C	W	C	C at W	W at C
SE_d	0.4	0.4	0.4	0.5	0.4	0.3	0.5	0.5
CD (P=0.05)	1.0	0.9	1.0	1.1	1.0	0.8	1.2	1.2

Treatment	Root dry weight (g m^{-2})							
	2011-12				2012-13			
	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean
W_1	29.8	32.4	39.7	34.0	25.7	31.0	41.7	32.8
W_2	24.0	23.8	30.2	26.0	17.6	20.4	30.6	22.9
W_3	24.3	21.7	36.5	27.5	20.5	22.7	37.1	26.8
W_4	26.8	29.4	38.4	31.5	24.0	31.3	40.9	32.1
W_5	22.5	23.1	35.2	26.9	21.3	21.6	36.1	26.3
W_6	16.6	20.7	21.9	19.7	12.4	15.3	20.6	16.1
Mean	24.0	25.2	33.6		20.2	23.7	34.5	
	W	C	C at W	W at C	W	C	C at W	W at C
SE_d	0.6	0.7	0.5	0.8	0.5	0.3	0.7	0.6
CD (P=0.05)	1.4	1.7	1.2	1.7	1.3	0.7	1.5	1.3

Treatment	Root length (cm)							
	2011-12				2012-13			
	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean
W_1	19.9	23.1	25.4	**22.8**	19.3	25.5	29.3	**24.7**
W_2	17.3	22.0	23.1	**20.8**	15.8	21.4	24.6	**20.6**
W_3	18.2	22.3	23.4	**21.3**	17.0	23.5	25.3	**21.9**
W_4	19.5	22.5	24.9	**22.3**	19.3	23.0	28.0	**23.4**
W_5	18.0	22.1	23.2	**21.1**	17.6	22.0	25.3	**21.6**
W_6	8.1	15.2	18.8	**14.0**	8.4	15.1	19.2	**14.2**
Mean	**16.8**	**21.2**	**23.2**		**16.2**	**21.7**	**25.3**	
	W	C	C at W	W at C	W	C	C at W	W at C
SE_d	0.4	0.8	0.5	0.8	0.4	0.3	0.5	0.5
CD (P=0.05)	1.1	2.0	1.3	1.7	1.0	0.8	1.1	1.1

irrigation practiced on soils had deeper and stronger root systems, without physical barriers to root growth. This effect was strengthened by planting young, single seedling at wider spacing. This is in conformity with the findings of Stoop *et al.* (2002). The reports of Mishra and Salokhe (2008) also confirmed improved root characteristics like root length, density and root weight when younger seedlings are transplanted than older ones.

Among the weed management practices, conoweeding four times at 10 days interval starting from 10 DAT (W_1), recorded lucidly higher root dry weight, which was on par with Pretilachlor treatment followed by Bispyribac sodium + conoweeding on 40 DAT (W_4) when compared to other in treatments. This is in line with the findings of Uphoff (2002) who had revealed that frequent stirring of soil by conoweeding facilitated better growing environment and enhanced the root characteristics resulting in the formation of more number of roots. He also stated that pruning of some of the upper roots encouraged deeper root growth, thereby increasing the root dry weight and root length.

Crop establishment methods and weed management practices had significant interactions with each other during both the years. Mechanical transplanting with conoweeding four times at 10 days interval starting from 10 DAT (C_3W_1) recorded significantly higher root dry weight, length and volume. This is in accordance with the findings of Vijayakumar *et al.* (2006), who had reported that younger seedlings will have more vigour and root growth. Further, Singh and Vatsa (2006) had reported that conoweeding had provided more air in the soil and greater root growth for better access to nutrients under SRI as compared to CTS. Such conditions would also support more aerobic soil biota. Leaving wider spacing between plants in machine planting (fewer plants per unit area) gives more nutrients to each plant as roots will have more adequate room to grow, However, this method was comparable to mechanical transplanting Pretilachlor followed by the Bispyribac sodium + conoweeding on 40 DAT (C_3W_4) over all the other combinations.

Nutrient uptake by crop

Crop establishment methods and weed management practices had significant influence on nutrient uptake by crop on 40 DAT during both the years of experimentation (Table 2). Among the horizontal strips, SRI mechanical transplanting (C_3) recorded significantly higher uptake which was on par with SRI marker planting than conventional planting. Mechanical planting and SRI marker planting with wider spacing and young seedlings recorded longer roots since higher plant density in these methods could increase the length of roots due to competition for uptake of water and nutrients from the soil. Sridevi and Chellamuthu (2012) reported that conoweeding had enhanced better root activity resulting in better uptake and translocation of nutrients from the soil. Joeli Barison (2002) reported that greater nutrient uptake might be due to some increase of available N in the soil as a result of higher mineralization of organic-N in a soil environment that alternates aerobic and anaerobic conditions. Furthermore, greater activity of N-fixing bacteria such as N_2-fixing endophytes within the root

Table 2. Effect of crop establishment methods and weed management practices on nutrient uptake (kg ha^{-1}) in rice on 40 DAT

Treatment	Nitrogen								Phosphorous								Potassium							
	2011-12				2012-13				2011-12				2012-13				2011-12				2012-13			
	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean
W_1	34.0	44.8	53.1	44.0	34.7	37.9	41.3	38.0	11.0	14.5	14.8	13.4	15.5	18.1	17.2	17.0	45.3	60.3	62.0	55.9	34.8	46.1	45.8	42.2
W_2	27.1	33.6	31.3	30.7	26.5	27.5	26.6	26.8	4.5	8.2	8.6	7.1	7.9	10.3	11.3	9.8	35.1	46.3	48.3	43.3	24.1	33.0	28.3	28.5
W_3	28.8	36.9	35.9	33.9	28.7	30.4	32.1	30.4	6.5	9.7	9.8	8.7	10.3	14.1	14.2	12.8	36.7	53.5	53.2	47.8	26.0	39.5	33.4	33.0
W_4	31.3	43.6	40.3	38.4	33.3	39.1	39.2	37.2	9.8	11.1	11.1	10.7	14.5	17.7	18.0	16.7	42.0	58.9	60.6	53.8	32.7	47.0	44.5	41.4
W_5	31.0	39.5	36.6	35.7	32.3	33.0	32.9	32.7	7.2	7.3	7.9	7.5	11.4	14.3	14.5	13.4	38.3	56.4	47.6	47.4	28.6	42.4	34.7	35.3
W_6	19.4	21.2	24.4	21.7	13.6	14.8	19.4	15.9	4.0	5.6	7.0	5.5	5.2	8.0	8.7	7.3	26.2	41.6	42.7	36.8	15.7	23.8	27.0	22.2
Mean	28.6	36.6	36.9		28.2	30.5	31.9		7.2	9.4	9.9		10.8	13.7	14.0		37.2	52.8	52.4		27.0	38.6	35.6	
	W	C	C at W	W at C	W	C	C at W	W at C	W	C	C at W	W at C	W	C	C at W	W at C	W	C	C at W	W at C	W	C	C at W	W at C
SE_d	0.9	0.9	0.9	1.1	0.9	0.7	1.2	1.2	0.2	0.2	0.2	0.3	0.3	0.2	0.4	0.4	1.1	0.9	1.1	1.2	0.9	0.7	1.1	1.1
CD (P=0.05)	2.3	2.1	2.1	2.5	2.3	1.7	2.7	2.6	0.6	0.6	0.6	0.7	0.7	0.4	0.8	0.8	2.7	2.1	2.6	2.7	2.2	1.7	2.5	2.5

cells and in the root rhizosphere might also be present in the SRI plant-soil environment. Phosphorus and potassium uptake was also higher with SRI, which might be due to enhanced root activity, allowing the plants to access the sub soil nutrients.

Among the vertical strips, conoweeding four times at 10 days interval starting from 10 DAT (W_1) resulted in significantly higher nutrient uptake by rice. This was due to the lower weed density, dry weight and efficient weed control noticed at early stage of crop weed competition. The reduced weed growth with consequent decreased nutrient depletion enabled more nutrient uptake by the rice crop in this weed management practice. This is in conformity with the findings of Mohamed Ali and Sankaran (1986) and Rajkhowa *et al.* (2001) who reported increased N, P and K uptake by rice through effective weed management practices.

Crop establishment methods and weed management practices had significant interaction with each other at all the stages of crop growth SRI machine transplanting with conoweeding four times at 10 days interval starting from 10 DAT (C_3W_1) recorded higher NPK uptake than the other combinations. Frequent stirring of soil by conoweeding caused pruning of roots that had encouraged the proliferation of roots. Also by conoweeding, weeds are incorporated into the soil reducing the weed dry weight and created a beneficial soil environment for rice growing.Better nutrient uptake with optimization of air and water in the soil was evident. This results are in line with the findings of *Xu et al.* (2003); Satyanarayana (2005) and Rupela *et al.* (2006). Unweeded control recorded the lowest nutrient uptake by plants. This might be due to depletion of nutrients by weeds in higher amount resulting in limited nutrients availability to the crop. Babar and Velayutham, (2012) stated that unchecked weed growth had caused significantly higher nutrient drain, which might otherwise be available to the crop.

Yield

Crop establishment methods and weed management practices had significant influence on grain yield (kg ha^{-1}) of rice (Table 3). The SRI machine transplanting (C_3) produced distinctly more grain yield than conventional transplanting (CT). However, it was comparable with SRI marker planting (C_2). This might be due to less crop weed competition, larger root system, crop canopy and higher microbial population, which might have facilitated the enhanced nutrient uptake, photosynthetic activity and remobilization of photosynthates to grain resulting in higher yield attributes and yield. This is in accordance with the findings of Hugar *et al*. (2009), who stated that SRI had given higher grain yield due to large root volume, strong tillers with improved yield attributes. Veeraputhiran *et al*. (2012) also reported that higher root volume and root weight

Table 3. Effect of crop establishment methods and weed management practices on grain and straw yield (kg ha^{-1}) in rice

Treatment	Grain yield (kg ha^{-1})								Straw yield (kg ha^{-1})							
	2011-12				2012-13				2011-12				2012-13			
	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean
W_1	4748	6477	6982	6069	5193	7119	7617	6643	10448	11245	12433	11375	11128	11022	13426	11859
W_2	4286	5542	6015	5281	3984	6039	6041	5355	8856	9408	10128	9464	8372	9701	10719	9597
W_3	3842	4839	4679	4453	3725	5310	4565	4533	7949	9725	10693	9456	7341	8795	10509	8882
W_4	4629	6376	6795	5933	4665	7818	7615	6700	10335	10988	11793	11039	10842	11804	13034	11893
W_5	4433	6063	6752	5749	4435	7019	7081	6178	8809	9857	10493	9720	10136	10290	11459	10628
W_6	2479	2913	3054	2815	2126	2411	2973	2503	6428	7306	8143	7292	6684	7430	8095	7403
Mean	4070	5368	5713		4021	5953	5982		8804	9755	10614		9084	9840	11207	
	W	C	C at W	W at C	W	C	C at W	W at C	W	C	C at W	W at C	W	C	C at W	W at C
SE_d	128	176	162	221	121	103	147	158	129	131	199	222	195	142	245	246
CD(P=0.05)	314	431	383	484	296	252	339	347	317	321	459	480	477	347	556	540

under SRI had helped in more nutrients and water uptake, which in turn improved the production of more tillers and filled grains. This could be the reason for higher yield attributes under SRI.

Conoweeding four times at 10 days interval starting from 10 DAT (W_1) was statistically significant by recording higher grain yield, which was on par with Pretilachlor followed by Bispyribac sodium + conoweeding on 40 DAT (W_4) than unweeded control (W_6). It might be due to reduced weed growth and higher weed control efficiency at early stages crop weed competition. This treatment also increased NPK uptake by the crop, in turn increasing the growth, yield attributes and yield. Thiyagarajan *et al.* (2002) also indicated that use of conoweeder resulted in increased yield of rice. The SRI machine transplanting with conoweeding four times at 10 days interval starting from 10 DAT (C_3W_1) registered higher grain and straw yield than other combinations. This might be mainly due to larger canopy with greater root development and activity, less intra plant competition, improved remobilization of assimilates to grain. The least grain yield was recorded under conventional planting with unweeded check (C_1W_6). Significant difference due to the crop establishment methods and weed management practices was evident during both years (Table 3). Revathi (2009) also reported higher straw yield in SRI due to higher tillers and DMP.

From the present findings it is concluded that SRI machine transplanting with cono weeding 4 times at 10, 20, 30, 40 DAT of rice will be the most effective method in enhancing root growth, nutrient uptake, grain and straw yield in rice. However, under labour shortage, machine planting with application of Pretilachlor (0.75 kg a.i. ha^{-1} pre-emergence) + Bispyribac sodium (20 g a.i. ha^{-1} early post-emergence) + conoweeding at 40 DAT can also be recommended.

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