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Effect of dates and methods of winter rice (*Oryza sativa* L.) transplanting on relayed field pea (*Pisum sativum*) and soil health

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ABSTRACT

A field experiment was conducted at Shillongani, Regional Agricultural Research Station, Nagaon, Assam during kharif - rabi seasons in the year 2014-15 and 2015-16 to study the effect of dates of transplanting under different methods of cultivation on productivity of winter rice (Oryza sativa L.) and their effect on rice-pea (Pisum sativum) relay system. Rice transplanted on 20th June recorded significantly higher yield attributes and grain yield of rice as compared to the later dates of transplanting, and it was followed by the 5th July- transplanted rice. Transplanting on 20th June resulted in higher values in respect of yield attributes, yield of relayed pea, rice equivalent yield (REY) of rice- pea relay system, NPK uptake by rice and pea as well as soil fungal and bacterial population after harvest of rice and pea. System of Rice Intensification (SRI) recorded significantly higher values of yield attributes and grain yield of rice as compared to conventional method. In case of pea, yield attributes, seed yield and REY were found slightly higher under conventional method of rice cultivation. Under SRI method, higher uptake of NPK by rice and pea and higher soil fungal and bacterial populations after harvest of rice and pea were observed as compared to conventional method. However, conventional method of rice cultivation recorded significantly higher values of soil available N, P_2O_5 and K_2O content at the end of two year-crop cycle over that of SRI.

***Keywords*:** Date of transplanting, field pea, method of cultivation relay, rice, soil health and SRI

In Assam, among the food crops, rice is the main food crop, occupying first position in respect of both area and production (Anon., 2014a). Pulses, in addition to rice, are also important food grains for which soil and climatic conditions of Assam are very congenial. Area under rice, pulses and oilseeds is about 65%, 8% and 4% of the total gross cropped area (38.43 lakh ha) of Assam. In 2012-13, the state was able to produce about 52.33 lakh t of total rice from an area of 24.88 lakh ha but the production of pulses were very low i.e. 0.85 lakh t from 1.42 lakh ha (Anon., 2014a and Anon., 2014b). Assam has achieved near self-sufficiency in rice production, however, it continues to be deficit in pulses. The requirement of pulses for the state was 3.78 lakh t in 2015-16 (Anon., 2016c). This shows a deficit of 2.57 lakh t (i.e. 68% of requirement). Therefore, productions of pulses, along with rice, also need special attention to meet their requirement for the burgeoning population. In Assam, rice- lands can easily be targeted for crop intensification. To increase pulse production, the cultivated land area cannot be increased directly. In such cases, crop intensification through multiple cropping in rice and rice based cropping systems are of prime importance (Deka *et al.*, 2013).

Although rice is grown in three different seasons, among them winter rice, locally known as S*ali* rice, is the most important one, which occupies about 75% of total rice area, covering an area of 18-19 lakh ha contributing to 65.37% of the total rice production in the state (Anon., 2014a and Anon., 2014b). *Sali* rice is grown on medium to low lands during June/July to November/December. In Assam, productivity of winter (*Sali)* rice is low (2055 kg ha^{-1}as compared to summer (boro) rice (2865 kg ha^{-1}. Moreover, most of the farmers are small and marginal having fragmented land holding. In this case, the winter rice productivity can be increased by adoption of SRI.

One of the major constraints of growing *rabi* crops after *Sali* rice is delayed harvesting of *Sali* rice and problem of land preparation due to excessive residual soil moisture. However, this constraint can be overcome by growing *rabi* crops as relay crops with rice. Pea is mostly grown after *winter* rice as a relay crop in major pea growing areas (Gupta and Bhowmick, 2005). It is evident that relay cropping of certain pulses with winter rice is quite feasible and profit-making. However, detailed study on relay cropping of pulses in relation to production system sustainability is not yet done. Further, relay cropping of pea with different dates of winter rice transplanted adopting SRI is not at all investigated for feasibility. Therefore, it becomes imperative to undertake the study to find out the optimum date of transplanting and method of cultivation of rice for increasing the productivity of rice-pea relay cropping system.

MATERIALS AND METHODS

A field experiment was carried out during the rainy (*kharif*) and winter (*rabi*) seasons of 2014-15 and 2015-16 at the Research Farm of Regional Agricultural

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Research Station, Shillongani, Nagaon, Assam. It is located between $26^{0}0^{\prime}$N latitude and $90^{0}45^{\prime}$E longitude and at an altitude of 50.2 m above from the mean sea level. The climate of this region is sub-tropical with hot humid summer and relatively dry and cold winter. The crop experienced favourable weather conditions in both the years of experimentation. Total amount of rainfall received during the crop growing period were 1771.7 mm during 2014-15 and 1935.6 mm during 2015-16 (Source: Gramin Krishi Mausom Sewa, RARS, Shillonani, Nagaon). . During rainy season, excess water causes stagnation and flood in many areas. In winter, water table recedes beyond root zone of the field crops. The maximum temperature rises up to 36^{0} C in July-August and the minimum falls to 7^{0}C in January and the relative humidity is about 80%.The soil of the experimental site was sandy loam in texture, acidic in reaction (pH 5.61), medium in organic carbon (0.84 %), medium in available N (296 kg ha^{-1}), P_2O_5 (21 kg ha^{-1}) and K_2O (195 kg ha^{-1}). All the plots were fertilized with recommended dose of fertilizers as per the crops grown in different seasons. The treatments comprised three dates of rice transplanting *viz*., 20th June, 5th July and 20th July and two methods of rice cultivation *viz*., conventional and SRI method with pea as relay crop. The experiment was laid out in a Factorial Randomized Block design with six treatment combinations replicated four times.

Winter rice variety 'Ranjit' (source: RARS, AAU, Titabor, Assam) and pea variety 'Aman' (IIPR, Kanpur) were used for study. Pea Seeds were broadcast @ 80 kg ha^{-1} in the standing rice crop at soil moisture saturation. Based on proper soil moisture content, pea was sown on 1st November in 2014 and 26th October in 2015. Rice was harvested from net plot while pea was harvested from gross plot. Soil samples were collected before sowing and at the end of second year to analyse for chemical properties following standard procedures. The plant samples (both seed and stover) of rice and pea were collected separately after threshing and dried in oven at 65^{0} C for 72 hrs. The oven-dried samples were finely ground and chemically analysed for N content by modified Kjeldahl method (Jackson, 1973), P colorimetrically by tri-acid digestion and yellow colour method (Jackson,1973) and K by flame photometer as described by Jackson (1973). The uptake of nutrients was calculated by multiplying the dry matter yield with respective percentage of nutrients.

For counting of soil microbial population *viz*., fungal and bacterial, soil samples from 0-15 cm depth from three spots of each plot were collected before transplanting of rice and at harvest of each crop and then fungal and bacterial populations in soil were enumerated by following the standard serial dilution technique and pour-plate method using different media (Aneja, 2003). For enumeration of bacterial population nutrient agar media and that for fungal population potato dextrose agar media were used. The bacterial population was counted on third day and that of fungal population on fifth day of incubation using the following formula.

Total viable count= Average number of colonies x size of aliquot x Dilution factor

The REY of relay pea and rice-pea relay system were calculated by using the following formula (Lal and Roy, 1976).

REY of pea = $\dfrac{\text{Yield of pea (q ha}^{-1}\text{) x price of pea (Rs. q}^{-1}\text{)}}{\text{Price of rice (Rs. q}^{-1}\text{)}}$

REY of rice-pea relay system = Rice yield + REY of pea

Gross return of rice -relay system = REY of rice-relay system (q ha^{-1}) x price of rice (q ha^{-1})

The data pertaining to each of the characters of the experimental crops were tabulated and finally analyzed statistically. Analysis of variance for Factorial RBD was worked out as per the standard procedure and the significance or non-significance of the variances due to treatment effects was tested by 'F' test. Critical difference was computed wherever 'F' test was significant.

RESULTS AND DISCUSSION

Yield attributes and grain yield of rice

The different dates of transplanting had no significant effect on panicle length in both the years (Table 1). Rice grown under SRI recorded significantly longer panicle (28.17 cm in 2014 and 27.89 cm in 2015) as compared to the conventional method. These results are in agreement with the findings of Singh *et al*. (2013) and Uzzaman *et al*. (2015). The highest panicle weight of 6.08 g panicle^{-1} and 5.96 g panicle^{-1} were recorded in the crops planted on 20th June which was at par with 5th July transplanting and was significantly higher than 20th July transplanting. This was due to production of higher number of filled grains panicle^{-1} in the former treatment. The methods of rice cultivation also exerted significant effect on panicle weight. The highest value (6.32 and 6.30 g panicle^{-1} during 2014 and 2015) was noted under SRI which was significantly higher than those under conventional method. Higher panicle weight was owing to higher number of filled grains panicle^{-1} under SRI. SRI accrued in significantly higher 1000-grain weight (20.50 and 20.43g in 2014 and 2015, respectively) than conventional method. These results are in conformity with the findings of Uzzaman *et al*. (2015) and Ranjitha and Reddy (2014). Higher 1000-grain weight in SRI might be due to better translocation of photosynthetates and dry-matter partitioning to the grains as compared to that under conventional method.

Table 1: Yield attributes and grain yield of rice as influenced by date of transplanting and method of cultivation

Treatment	Panicle length (cm)		Panicle weight (g panicle $^{-1}$)		1000-grain weight(g)		Grain yield (q ha^{-1})		
	2014	**2015**	**2014**	**2015**	**2014**	**2015**	**2014**	**2015**	**Pooled**
Date of rice transplanting									
20th June	27.20	26.79	6.08	5.96	20.12	20.03	59.61	58.79	59.19
5th July	27.08	26.56	5.78	5.84	19.97	19.91	58.44	57.73	58.09
20th July	26.85	26.43	5.33	5.26	19.95	19.94	55.92	55.16	55.55
SEm (±)	**0.85**	**0.66**	**0.18**	**0.20**	**0.12**	**0.11**	**1.11**	**1.02**	**0.99**
LSD (0.05)	**NS**	**NS**	**0.56**	**0.63**	**NS**	**NS**	**3.49**	**3.21**	**3.12**
Method of rice cultivation									
Conventional	25.92	25.30	5.15	5.08	19.54	19.49	55.21	54.54	54.99
SRI	28.17	27.89	6.32	6.30	20.50	20.43	60.77	59.91	60.34
SEm (±)	**0.69**	**0.54**	**0.14**	**0.17**	**0.10**	**0.09**	**1.04**	**0.96**	**0.88**
LSD (0.05)	**2.19**	**1.71**	**0.44**	**0.38**	**0.32**	**0.30**	**3.28**	**3.05**	**2.77**
Interaction									
SEm (±)	**1.20**	**0.94**	**0.27**	**0.39**	**0.17**	**0.16**	**1.98**	**1.87**	**1.79**
LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Table 2: Total NPK-uptake by rice at harvest as influenced by date of transplanting and method of cultivation of rice

Treatments	Total N-uptake (kg ha^{-1})		Total P-uptake (kg ha^{-1})		Total K-uptake (kg ha^{-1})	
	2014	**2015**	**2014**	**2015**	**2014**	**2015**
Date of rice transplanting						
20th June	68.49	66.08	22.08	20.56	62.69	60.96
5th July	67.05	64.68	21.03	19.77	61.34	60.21
20th July	62.99	64.43	19.26	18.19	58.40	56.42
SEm (±)	**2.21**	**1.63**	**0.55**	**0.35**	**1.62**	**1.63**
LSD (0.05)	**NS**	**NS**	**1.75**	**1.09**	**NS**	**NS**
Method of rice cultivation						
Conventional	63.26	60.69	19.71	18.47	58.49	56.43
SRI	69.10	69.43	21.88	20.54	63.13	61.97
SEm (±)	**1.79**	**1.33**	**0.45**	**0.28**	**1.32**	**1.33**
LSD (0.05)	**5.66**	**4.19**	**1.43**	**0.89**	**4.18**	**4.19**
Interaction						
SEm (±)	**3.11**	**2.31**	**0.784**	**0.491**	**2.30**	**2.31**
LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Table 3: Yield attributes and grain yield of pea as affected by transplanting date and method of cultivation of rice

Treatments	Pod plant^{-1}		Grains pod^{-1}		1000- seed weight (g)		Grain yield (q ha^{-1})	
	2014-15	**2015-16**	**2014-15**	**2015-16**	**2014-15**	**2015-16**	**2014-15**	**2015-16**
Date of rice transplanting								
20th June	21.85	24.24	6.22	6.63	207.10	207.24	16.41	18.51
5th July	21.50	23.87	6.21	6.62	207.07	207.20	16.13	18.02
20th July	19.95	22.45	5.72	6.27	206.60	206.79	15.71	17.32
SEm (±)	**0.56**	**0.53**	**0.35**	**0.27**	**0.93**	**0.94**	**0.16**	**0.19**
LSD (0.05)	**1.78**	**1.38**	**NS**	**NS**	**NS**	**NS**	**0.52**	**0.61**
Method of rice cultivation								
Conventional	21.32	23.64	6.09	6.59	206.93	207.11	16.09	17.97
SRI	20.88	23.40	6.01	6.42	206.91	207.04	16.07	17.93
SEm (±)	**0.46**	**0.43**	**0.29**	**0.23**	**0.76**	**0.77**	**0.13**	**0.16**
LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Interaction								
SEm (±)	**0.80**	**0.76**	**0.50**	**0.39**	**1.32**	**1.33**	**0.22**	**0.27**
LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Table 4: Rice equivalent yield of pea and rice-pea relay system as influenced by date of transplanting and method of cultivation of rice

Treatments	Rice equivalent yield (q ha^{-1})			Rice equivalent yield of rice-pea relay system (q ha^{-1})		
	2014-15	**2015-16**	**Pooled**	**2014-15**	**2015-16**	**Pooled**
Date of rice transplanting						
20th June	45.95	51.83	48.89	105.52	111.41	108.46
5th July	45.16	50.46	47.81	103.62	108.91	106.26
20th July	43.98	48.49	46.23	99.91	104.41	102.16
SEm (±)	**0.44**	**0.54**	**0.35**	**2.03**	**2.00**	**2.21**
LSD (0.05)	**1.40**	**1.72**	**1.09**	**NS**	**NS**	**NS**
Method of rice cultivation						
Conventional	45.09	50.31	47.66	100.26	105.41	102.83
SRI	45.02	50.20	47.64	105.77	111.07	108.42
SEm (±)	**0.36**	**0.44**	**0.28**	**1.66**	**1.63**	**0.99**
LSD (0.05)	**NS**	**NS**	**NS**	**5.23**	**5.14**	**3.13**
Interaction						
SEm (±)	**0.67**	**0.77**	**0.49**	**2.87**	**2.83**	**1.72**
LSD (0.05)	**NS**	**NS**	**1.55**	**NS**	**NS**	**NS**

Note: Sale price of seeds of rice = Rs.1250.00 q^{-1} and pea = Rs. 3500.00 q^{-1}

Table 5: Total NPK-uptake by pea at harvest as influenced by date of transplanting and method of cultivation of rice

Treatments	Total uptake by pea (kg ha^{-1})					
	N-uptake (kg ha^{-1})		P-uptake (kg ha^{-1})		K-uptake (kg ha^{-1})	
	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
Date of rice transplanting						
20th June	100.86	113.81	19.89	23.29	59.87	68.59
5th July	98.19	109.76	19.24	22.05	57.66	65.91
20th July	91.33	100.99	15.70	17.83	52.67	59.52
SEm (±)	**1.20**	**1.83**	**0.43**	**0.36**	**1.10**	**1.03**
LSD (0.05)	**3.80**	**5.79**	**1.35**	**1.15**	**3.48**	**3.25**
Method of rice cultivation						
Conventional	97.12	108.29	18.42	21.12	57.06	64.99
SRI	96.46	108.09	18.14	20.99	56.40	64.36
SEm (±)	**0.98**	**1.50**	**0.35**	**0.29**	**0.90**	**0.84**
LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Interaction						
SEm (±)	**1.70**	**2.60**	**0.60**	**0.51**	**1.56**	**1.46**
LSD (0.05)	**5.37**	**8.19**	**1.91**	**1.62**	**4.92**	**4.60**

Table 6: Soil fungi and bacteria population after harvest of rice and pea as influenced by date of transplanting and method of cultivation

Treatments	After rice harvest				After pea harvest			
	Fungi (10^5 cfu g soil^{-1})		Bacteria (10^5 cfu g soil^{-1})		Fungi (10^5 cfu g soil^{-1})		Bacteria (10^5 cfu g soil^{-1})	
	2014	2015	2014	2015	2014	2015	2014	2015
Date of rice transplanting								
20th June	26.33	29.03	36.53	39.6	55.10	57.83	71.30	74.53
5th July	26.10	28.53	36.36	39.43	51.93	55.66	69.66	72.56
20th July	25.33	27.73	32.93	36.16	51.9	55.46	68.86	71.93
SEm (±)	**1.36**	**1.34**	**1.99**	**1.66**	**3.68**	**3.37**	**4.19**	**3.96**
LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Method of rice cultivation								
Conventional	25.76	28.15	35.10	38.30	51.84	55.24	68.68	71.86
SRI	26.25	28.70	35.45	38.49	54.11	57.40	71.20	74.15
SEm (±)	**1.11**	**1.10**	**1.62**	**1.36**	**3.01**	**2.75**	**3.42**	**3.24**
LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Interaction								
SEm (±)	**2.73**	**2.71**	**3.99**	**3.33**	**5.21**	**4.76**	**5.93**	**5.61**
LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Note: Initial soil fungal population = 36.53 (10^5 cfu g soil^{-1}), Initial soil bacterial population = 48.13 (10^5 cfu g soil^{-1})

Table 7: Effect of date and method of rice transplanting and relay crop on available N, P_2O_5 and K_2O content in soil at the end of two year-crop cycle

Treatments	Available N, P_2O_5 and K_2O content (kg ha^{-1})		
	N content(kg ha^{-1})	P_2O_5 content (kg ha^{-1})	K_2O content (kg ha^{-1})
Date of rice transplanting			
20th June	187.15	12.96	128.15
5th July	199.51	13.55	132.45
20th July	226.99	20.12	147.63
SEm (±)	**0.48**	**0.44**	**1.11**
LSD(0.05)	**1.51**	**1.38**	**3.51**
Method of rice cultivation			
Conventional	197.05	14.09	125.80
SRI	212.05	16.99	146.35
SEm (±)	**0.39**	**0.36**	**0.91**
LSD(0.05)	**1.23**	**1.13**	**2.86**
Interaction			
SEm (±)	**0.68**	**0.62**	**1.57**
LSD(0.05)	**2.14**	**1.96**	**4.97**

Different dates of transplanting brought about significant differences in grain yield (Table 1). Grain yield was found to decrease with delay in transplanting. The highest grain yield (59.61, 58.79 and 59.19 q ha^{-1} in 2014, 2015 and pooled, respectively) was recorded under 20th June which were at par with that of 5th July transplanting and were significantly higher than that of 20th July. Early transplanting favoured better uptake of N, P and K and thereby increased growth and yield attributes and ultimately reflected on yield. Higher grain yield under early planting might also be attributed to relatively early crop establishment and better tillering. Similar reduction in yield due to delayed transplanting was also reported by Ashem *et al.* (2010) and Changmai (2015). SRI gave significantly higher grain yield (60.77, 59.91 and 60.34 q ha^{-1} in 2014, 2015 and pooled, respectively) than conventional method. Similar results were also reported by Singh *et al*. (2013) and Ranjitha and Reddy (2014). The increase in grain yield under SRI was owing to vigorous root growth resulting in better N, P and K uptake and reproductive growth and ultimately higher yield of rice.

During both the years, there was no statistical difference in total N and K-uptake by rice due to different dates of transplanting. However, its effect on total P uptake was found significant (Table 2). The highest total P uptake (22.08 and 20.56 kg ha^{-1} in 2014 and 2015, respectively) was recorded in rice transplanted on 20th June and the lowest was in rice transplanted on 20th July. SRI resulted in significantly higher uptake of total N (69.10 and 69.43 kg ha^{-1}), P (21.88 and 20.54 kg ha^{-1}) and K (61.13 and 61.97 kg ha^{-1}) in 2014 and 2015, respectively as compared to the conventional method. This was due to the higher yield and higher N, P and K content in grain and straw which was, in turn, because of better vegetative and reproductive growth leading to production of more biomass. These results are in agreement with the findings of Vallois and Uphoff (2000) and Ranjitha and Reddy (2014). In SRI method, application of more organic manure along with inorganic fertilizers and incorporation of weeds by cono weeder increased release of nutrients to the soil, which led to enhanced biomass production and ultimately resulted in higher NPK uptake.

Yield attributes and grain yield of relayed pea

The number of pods plant^{-1} differed significantly due to varying dates of rice transplanting (Table 3). The highest number of pods plant^{-1} was recorded under rice transplanted on 20th June followed by 5th July and 20th July transplanted rice. Higher number of pods plant^{-1} with early transplanted rice was owing to better growth of the relay crop favoured by desired association with rice and timely sowing. The effect of methods of rice cultivation on pods plant^{-1} was found insignificant, and both the factors failed to exert significant effect on seeds pod^{-1}, 1000-grain weight of relayed pea. The highest grain yield of pea was resulted in by 20th June rice transplanting. The maximum pea yield under 20th June transplanting was owing to better plant stand and higher pods plant $^{-1}$ and seeds pod $^{-1}$. The findings are in conformity with those of Gupta and Bhowmick (2005) and Tripathi (1986). There was no statistical difference between two methods of rice cultivation in respect of grain yield of pea.

Rice equivalent yield (REY) of relayed pea and rice-pea relay system

The highest REY of pea was recorded under 20th June rice transplanting which was at par with 5th July (Table 4). However, there was significant reduction in REY of pea because of further delay in transplanting. The method of rice cultivation had no significant effect on it.

The date of rice transplanting showed non-significant effect on rice equivalent yield (REY) of rice-pea relay system. The method of rice cultivation had significant effect on REY of rice-pea relay system. REY of rice-pea system under SRI was significantly higher than the conventional method and this was mainly because of the higher yield of rice under this treatment.

Total NPK-uptake by pea

The highest total N, P and K-uptake by pea was recorded under 20th June rice transplanting which was at par with 5th July transplanting, and both dates of transplanting were superior to 20th July transplanting (Table 5). Higher biomass production in pea under 20th June rice transplanting resulted in higher total N, P and K- uptake under this treatment. Method of rice cultivation had no significant effect on nutrient uptake by pea.

Soil fungal and bacterial population after rice and pea harvest

The different dates of transplanting and method of rice cultivation did not exert significant effect on soil fungal and bacterial population after rice and pea harvest (Table 6).

Soil nutrient (NPK) status at the end of two year crop cycle

The dates of rice transplanting brought about significant differences in available N, P_2O_5 and K_2O content in soil recorded (Table 7). The lowest available N, P_2O_5 and K_2O in soil was recorded under 20th June transplanting. As N, P and K uptake by rice and pea was higher under 20th June transplanted rice as compared to latter dates of transplanting, lower available soil N, P_2O_5 and K_2O after harvest of pea was the resultant. Method of rice cultivation had also significant effect on the available N, P_2O_5 and K_2O in soil. Significantly higher available N, P_2O_5 and K_2O (212.05, 16.99 and 146.35 kg ha^{-1}, respectively) was found under SRI as compared to conventional method. Higher soil N, P_2O_5 and K_2O under SRI might be owing to more nutrient availability and higher soil microbial population resulting from application of organic manure. Similar findings were also reported by Singh *et al*. (1999) and Manna *et al*. (2006).

From this study, it can be concluded that the present study gave a direction for adopting suitable method and time of winter rice transplanting for maximizing yield of rice-pea relay cropping in Assam. By growing rice crop adopting SRI and transplanting on 20th June, yields of both the crops in rice-pea relay system and the rice-equivalent yield of the system can be increased to their potential levels.

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