DOI: 10.15740/HAS/AU/12.TECHSEAR(2)2017/452-458
Agriculture Update
Volume **12** | TECHSEAR-2 | 2017 | 452-458
Visit us : *www.researchjournal.co.in*
e ISSN-0976-6847

RESEARCH ARTICLE :

Rice establishment techniques and co-cultivation of green manure on productivity and economics of rice

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ARTICLE CHRONICLE :
Received :
11.07.2017;
Accepted :
24.07.2017

SUMMARY : Field experiments were conducted at Agricultural College and Research Institute, Killikulam during late Pishanam of 2013-14 and 2014-15 to evaluate different methods of rice establishment techniques and co-cultivation of green manures to enhance the rice productivity. The experiments were laid out in Randomized Block Design and replicated thrice. Rice ADT (R) 45 taken as test variety. Paddy direct seeding was taken up in the main field by using paddy drum seeder with a spacing of 20 cm between rows and paddy cum dhaincha seed drill with an interrow spacing of 25 cm between rice rows and 12.5 cm between rice and dhaincha in the respective plots. Simultaneously, rice nursery also taken separately for manual and machine transplanting. *Azolla* was applied in the respective plots on third days after paddy sowing / planting. The results shows that direct seeded rice with dhaincha / *Azolla* recorded higher plant height than the machine/ manual planted rice. Rice yield attributes remains unaffected by adoption of various rice establishment methods. But it was positively influenced by the adoption of green manure dhaincha intercropping / *Azolla* co-cultivation practices. Planting at 25 x 25 cm with dhaincha intercropping and its incorporation by conoweeder at 30 DAS recorded higher grain (6110 and 6324 kg / ha) and straw yield (6973 and 7358 kg / ha) during both the years, respectively. It was closely followed and statistically at par yield when the rice cultivated by machine planting at 25 x 17.5 cm with dhaincha intercropping and its incorporation by conoweeder at 30 DAS and / or direct sown rice using paddy cum dhaincha seed drill. Planting of rice at 25 x 25 cm with dhaincha intercropping and its *in-situ* incorporation by conoweeder at 30 DAS recorded higher gross income of Rs.94,239 and 97, 962 /ha. But direct seeding of rice using paddy cum dhaincha seed drill fetched with higher net income of Rs.55,088 and 58,067/ha and B:C ratio during both the years of study.

KEY WORDS :
Rice establishment methods, Co-cultivation of green manures, Growth, Yield

How to cite this article : Joseph, M. and Hemalatha, M. (2017). Rice establishment techniques and co-cultivation of green manure on productivity and economics of rice.*Agric. Update,* **12**(TECHSEAR-2) : 452-458; **DOI: 10.15740/HAS/AU/12.TECHSEAR(2)2017/452-458.**

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BACKGROUND AND OBJECTIVES

Rice (*Oryza sativa* L.) is one of the most important staple food crop in many Asian countries. In India, rice is cultivated in 44.1 million hectares with an annual production of about 105.5 million tonnes. In Tamil Nadu rice is grown in an area of 16.42 lakh hectares

with the production of 57.28 lakh million tonnes with an average productivity of 3,191 kg ha^{-1} (Indiastat, 2015). India made remarkable progress in increasing food grain production from 1950's. During the past, paddy production increased by 4.5 times and area by 42 per cent. This is a remarkable achievement, however, for the last decade or so, the production levels are stagnant.

Transplanting is the most dominant and traditional method of crop establishment in irrigated lowland rice. However, huge water inputs, high labour costs and labour requirements for TPR have reduced the profit margins (Pandey and Velasco, 1999). The rising labour cost, the need to intensify rice production through double and triple cropping, late onset of monsoon and delayed release of canal water provided the economic incentives for a switch to direct seeding. Simultaneously, the availability of high-yielding, short-duration varieties, and chemical weed control methods made such a switch technically viable.

Resource management in Agriculture could be sound and effective, if it encashes season, variety, even stages of a crop, cheaper sources of inputs etc., without detrimental to the crop yield and soil health. This is all more obvious against the back drop of soil health becoming deteriorated in increasing dimension and the productivity attaining a declining trend in crops like rice at global level. Added to this, 67 per cent of rice in India is estimated to be short of adequate nitrogen as was reported by Mahapatra *et al*. (1985). Massive promotion of organic manuring could correct all these reversing trends in Agriculture to a great extend Solaiappan *et al*. (1996). But, the bulkiness of organic manure and in consequence, costly affair of its application in this present day agriculture stand in the way of intensive use of them.

Rice tolerates intense shading during its vegetative phase with least unfavourable effect on yield Yoshida and Parao (1976). This fact could be used for intercropping of green manure at the early stage and incorporating it before rice become more sensitive to shading. After about 40-45 days growth, dhaincha is knocked down with the application 2, 4-D.The practices, which has also come to known as 'brown manuring' has the potential for adoption. The practices does not require additional water, the green manure acts as surface mulch, checks evaporation loss and acts as a source of nutrients upon decomposition. On the other hand, intercropping green manure in wet weeded rice could have more duration difference and further green manure herein could vacate the land by the time rice becomes more sensitive to shade.

As desired by the needs of intensive crop production, cultivation of *Sesbaniaaculeata* has now been successfully introduced in intercropping system under direct sown rice (Joseph, 1998). Under rice + dhaincha intercropping system the gains of N through green manuring have been measured either in terms of crop yield or residual soil fertility. The *Azolla*, another important bio-fertilizer which having nitrogen-fixing capability and extensively used to bolster the rice productivity in Asian countries. *Azolla*, a free-floating aquatic fern having symbiotic association with the N_2 fixing cyanobacterialsymbiont Anabaena *Azollae* can fix 30-60 kg N/ha in 30 days. It is either incorporated as green manure at the beginning of the cropping season or grown as a dual crop along with rice in the standing water of flooded fields. Hence, the study was taken up with different rice establishment techniques along with co-cultivation of green manures to enhance the rice productivity.

RESOURCES AND METHODS

Field experiments were conducted at BC block, Agricultural College and Research Institute, Killikulam during late Pishanam of 2013-14 and 2014-15 to evaluate different methods of establishment techniques of rice and Co-cultivation of green manures to enhance the rice productivity. The experimental soil was clay loamy with a pH of 7.1 and 7.5 and the available NPK status were 280 and 271, 27 and 24 and 242 and 259 kg /ha during 2013-14 and 2014-15, respectively. The experiments were laid out Randomized Block Design and replicated thrice. Rice ADT (R) 45 taken as test variety.

The treatment consists of four method of rice establishment *viz.*, manual planting of rice at 25 x 25 cm spacing(T_1 - T_4), machine transplanting of rice at 25 x 17.5 cm spacing (T_5 - T_8), wet seeding by paddy cum Dhaincha seed drill (T_9 and T_{10}) and wet seeding by Drum seeded (T_{11} and T_{12}). Dhaincha green manure and *Azolla* was co-cultivated between the rice row spaces.

Paddy direct seeding was taken up in the main field by using paddy drum seeder with a spacing of 20 cm between rows and paddy cum dhaincha seed drill with a inter row spacing of 25 cm between rice rows and 12.5 cm between rice and dhaincha in the respective plots. Simultaneously, rice nursery also taken separately for

manual and machine transplanting.

Machine and manual transplanting was taken up in the main field accordingly. *Azolla* was applied in the respective plots on third days after paddy sowing / planting. Intercropped green manure / *Azolla* were *in-situ* incorporated in the respective plots using conoweeder on 30 DAS of green manure crops. Similarly dhaincha plants are desiccated by spraying post-emergence herbicide 2, 4-D @ 1.25 kg / ha and then *in-situ* incorporated as per the treatments.

Biometric observations on dhaincha like plant population m^{-2}, plant height, biomass production, number of nodules plant $^{-1}$ and N accumulation were recorded. Similarly, biomass production and N accumulation of *Azolla* were also recorded at the time of incorporation.

In rice, biometric observations, yield attributes, yield and post harvest available N status were recorded. Economics of various treatments are also worked out and presented below.

OBSERVATIONS AND ANALYSIS

The results obtained from the present study as well as discussions have been summarized under following heads:

Growth characters of inter sown dhaincha :

Population of dhaincha intersown with rice under different establishment methods ranged between 47.5 to 52.0 m^{-2} and 51.0 to 58.0 m^{-2} with a plant height of 49.3 to 61.7 cm and 53.8 to 66.6 cm during 2013-14 and 2014-15, respectively at the time of its *in-situ* incorporation (30 DAS) (Table 1).

Number of root nodules/plant and biomass production recorded considerably from 30 to 38.0 and 28 to 37 root nodules /plant and 5120 to 6333 kg/ha and 6055 to 6973 kg/ha biomass, respectively at the time of incorporation under various treatments during the two years. Similarly co-cultivation of *Azolla* with rice also recorded the biomass production of 4616 to 5218 and 4536 – 5040 kg /ha at the time of incorporation (30 DAS) during the period of observations.

Nitrogen accumulation:

Green manure plant samples collected for recording drymatter production at the time of incorporation were chopped, dried in hot air oven at 80 $\pm$ 5°C for 72 hours and ground into fine powder in a willey mill. The powdered samples were used for the N analysis and expressed in percentage on oven dry wet basis. The nutrient accumulation was worked by multiply the DMP with N content and expressed in kg/ha.The N ccumulation by dhanicha incorporation was ranged from 21.8 to 26 and 25.5 to 28.7 kg ha^{-1} and by *Azolla* from 14 to 15.5 and 13.7 to 14.5 kg ha^{-1} during the two years of

Table 1: Effect of rice establishment method and co-cultivation of green manure on growth parameters and N accumulation of Dhaincha and *Azolla* at the time of incorporation

Treatments	Dhaincha										*Azolla*			
	Plant population/m^2		Plant height (cm)		No. of root nodules / plant		Biomass production (kg/ha)		N accumulation (kg/ha)		Biomass production (kg/ha)		N accumulation (kg/ha)	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
T_1	47.5	54.0	49.7	53.8	33.0	28.0	5120	6258	21.8	25.5	-		-	-
T_2	49.5	51.0	52.3	61.0	30.0	34.0	5462	6525	22.6	27.2	-	-	-	-
T_3	-	-	-	-	-	-	-	-	-	-	4616	4536	14.0	13.7
T_4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
T_5	49.0	52.0	49.3	63.4	34.0	31.0	5326	6973	22.3	28.7	-	-	-	-
T_6	48.5	54.5	53.0	58.5	32.0	35.0	5532	6055	23.3	25.4	-	-	-	-
T_7	-	-	-	-	-	-	-	-	-	-	4755	4628	14.5	14.0
T_8	-	-	-	-	-	-	-	-	-	-	-	-	-	-
T_9	51.0	53.5	59.5	64.8	38.0	34.0	6333	6164	26.5	25.7	-	-	-	-
T_{10}	52.0	58.0	61.7	66.6	36.5	37.0	6320	6712	26.4	28.0	-	-	-	-
T_{11}	-	-	-	-	-	-	-	-	-	-	5218	5040	15.5	14.5
T_{12}	-	-	-	-	-	-	-	-	-	-	-		-	-

T_1 to T_4 - Manual transplanting : T_5 to T_8 - Machine transplanting : T_9 to T_{10} - Paddy cum Dhaincha drum seeder : T_{11} to T_{12} - Paddy drum seeder

experimental period.

Rice growth characters :

Plant height :

Co-cultivation of rice with Dhaincha /*Azolla* green manure, recorded more plant height than sole rice. At active tillering stage, the effect of various rice establishment methods was significantly influenced on plant height. Among the different methods of rice establishment, rice direct seeding either by using paddy cum dhaincha seed drill or paddy drum seeder recorded higher plant height of 60.1 to 63.2 and 65.7 to 67.8 cm during 2013-14 and 2014-15, respectively. The higher plant height recorded on direct seeded rice might be due to evading of transplanting shock period (Table 2).

At panicle initiation stages, direct seeded rice with dhaincha /*Azolla* recorded higher plant height of 93.3 to 96.7cm and 97.1 to 98.8 cm, respectively. Rice transplanting either with manual or machine and intercropped with dhaincha recorded statistically comparable rice plant height but higher than sole transplanted rice. At harvest stage the rice plant height was comparable with rice + dhaincha intercropping and its incorporation by 30 DAS either in direct seeded rice or manual transplanted rice. The similar line of results were recorded by Anitha and Mathew (2010)who observed that, plant height and tiller production of rice were significantly higher when dhaincha was incorporated at 30 DAS.

Total tiller production/m^2 :

Total tiller production counted at various stages and affected by different method of rice establishment and co-cultivation of dhaincha and (or) *Azolla*.

At active tillering stage, rice sown with drum seeder without any green manure intercropping recorded higher total tiller count of 476 and 480 per m^2. But rice intercropped with dhaincha or co-cultivation with *Azolla* recorded more or less similar range of tiller production.

On contrary at panicle initiation and at harvest stages, the tiller count was more pronounced under rice intercropping / co-cultivation system in irrespective of rice establishment methods than sole rice cultivation. Rice planting at 25 x 25 cm spacing + Co- cultivation of dhaincha and incorporation by TNAU power weeder at 30 DAS recorded higher tiller count of 542 and 561 numbers / m^2 at harvest stage during both the years, respectively. Rice planting at 25 x 25 cm spacing without any green manure recorded lower tiller count.

Rice yield attributes :

Productive tiller m^2:

Due to different rice establishment methods and co-cultivation of dhaincha and *Azolla* rice exhibited significant variation in productive tillers production. Maximum number of productive tillers 520 and 538 /m^2

Table 2: Effect of different rice establishment method and co-cultivation of green manure on rice growth characters

Treatments	Plant height (cm)						Total tiller production /m^2					
	Active tillering		Panicle initiation		At harvest		Active tillering		Panicle initiation		At harvest	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
T_1	46.5	48.2	89.2	92.6	104.7	108.6	432	428	538	550	542	561
T_2	47.1	50.5	92.1	95.4	106.4	109.7	454	448	510	523	527	540
T_3	51.2	53.7	90.4	93.0	103.2	107.5	436	430	502	526	518	537
T_4	44.7	48.1	85.8	88.1	98.9	102.2	402	412	438	461	442	470
T_5	53.1	56.0	92.2	95.3	104.4	107.6	459	460	522	534	536	552
T_6	54.7	56.1	87.5	89.8	103.6	107.0	425	434	508	528	523	548
T_7	47.5	50.9	88.0	91.0	102.3	105.7	431	444	489	497	502	529
T_8	48.0	51.2	84.6	86.8	99.6	103.5	451	468	471	486	478	504
T_9	62.3	60.5	93.3	97.2	104.1	108.4	452	464	521	539	531	563
T_{10}	61.4	66.4	95.0	98.8	107.4	112.4	449	470	500	520	527	552
T_{11}	63.2	67.8	96.7	97.1	112.6	117.9	448	456	520	537	528	550
T_{12}	60.1	65.7	93.5	96.0	109.5	113.5	476	480	505	518	519	543
S.E.±	1.5	1.5	2.9	3.1	3.6	3.3	16.1	13.9	17.4	15.3	19.8	18.4
C.D. (P=0.05)	3.3	3.4	6.3	6.7	7.3	7.0	34.7	30.5	38.1	32.6	42.3	40.3

was recorded under machine transplanted rice + dhaincha intercopping and its incorporation by conoweeder on 30 DAS during both the years of experiments. It was statistically at par with direct seeded rice by paddy drum seeder with or without green manure intercropping. Sole rice without green manure planted by manually recorded lower number of productive tiller (425 and 441m^{-2}) (Table 3).

Rice panicle length remains unaffected by adoption of various rice establishment methods. But it was positively influenced by the adoption of green manure dhaincha intercropping /*Azolla* co-cultivation practices. The higher value of panicle length (ranged from 17.3 to 19.2 cm) was recorded in the treatment plots which having rice + dhaincha / *Azolla* co-cultivating system in irrespective of different rice establishment methods. But sole rice in irrespective of rice establishment method recorded lower panicle length (16.6 to 17.8 cm).

Total number of grains per panicle and number of filled grains per panicle also proved the similar trends. The maximum number of grains per panicle (224 and 237/panicle) and number of filled grains per panicle (207 and 224) were recorded when the rice was directly sown in the main field by paddy cum dhaincha seed drill and it was followed by rice manual planting at 25 x 25 cm spacing and dhaincha intercropping and its incorporation by conoweeder on 30 DAS. Sole rice without green manure recorded minimum numbers of total and filled grains per panicle during both the years of study.The similar finding also reported by Anitha (2010) stated that rice intercropped with green manure produced more number of panicles, higher test weight and increased panicle weight.

Different rice establishment methods and with / without green manure intercropping recorded the 1000 grain weight which ranged between 17.3 and 18.2 g. but it was not significantly affected by method of rice establishment and co-cultivation of green manures.

Grain and straw yield :

Rice establishment method and co-cultivation of green manure significantly influenced on the grain and straw yield of rice. Planting at 25 x 25 cm with dhaincha intercropping and its incorporation by conoweeder at 30 DAS recorded higher grain (6110 and 6324 kg / ha) and straw yield (6973 and 7358 kg / ha) during 2013-14 and 2014-15, respectively. It was closely followed and statistically at par yield when the rice cultivated by machine planting at 25 x 17.5 cm with dhaincha intercropping and its incorporation by conoweeder at 30 DAS (T_5) and / or direct sown rice using paddy cum dhaincha seed drill (T_9). In irrespective of rice establishment method, rice (sole crop) without any green manure (or) co-cultivation of *Azolla* recorded lower grain

Table 3 : Effect of different rice establishment method and co-cultivation of green manure on rice yield and yield characters

Treatments	Productive tillers /m^2		Panicle length (cm)		Total grains /panicle		Filled grains /panicle		Test grain weight (g)		Grain yield (kg/ha)		Straw yield (kg/ha)	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
T_1	481	495	19.1	18.6	212	231	198	219	18.2	18.0	6110	6324	6973	7358
T_2	506	502	18.6	18.5	197	214	182	204	17.9	17.8	5770	6063	6429	6726
T_3	486	498	19.0	19.2	180	185	166	173	17.9	17.9	5875	6182	6639	6933
T_4	425	441	16.8	16.9	152	167	131	148	17.3	17.5	5075	5317	5606	5970
T_5	520	538	18.7	18.8	195	204	175	192	18.1	18.0	6080	6300	6848	7320
T_6	510	522	17.9	18.1	189	200	162	178	18.1	18.2	5510	5850	6259	6612
T_7	492	507	17.3	17.5	175	189	148	171	17.8	18.0	5675	5936	6405	6811
T_8	467	484	16.6	17.0	148	168	129	150	17.3	17.6	5150	5475	5792	6085
T_9	435	476	19.0	19.2	224	237	207	224	18.2	18.1	5935	6229	6767	7050
T_{10}	468	493	19.0	19.1	210	229	196	213	18.2	18.0	5570	5900	6229	6598
T_{11}	512	533	18.7	19.0	202	215	183	197	18.0	18.2	5695	5952	6427	6700
T_{12}	510	530	17.0	17.8	171	192	154	180	17.5	17.8	5220	5550	5773	6155
S.E.±	19.7	18.9	0.57	0.05	6.1	6.1	5.4	5.7	0.57	0.61	175	177.3	210	214
C.D.(P=0.05)	42.5	41.0	1.25	1.10	13.2	13.0	11.8	12.2	NS	NS	378	383	452	464

NS= Non-significant

and straw yield. The yield increase in these treatments might be the fact that steady and adequate supply of nutrients by the enhanced biochemical activities of micro-organisms coupled with large photosynthesizing surface would have helped in the production of more tillers and drymatter with enhanced supply of assimilate to sink resulting in higher yield. Similar results are reported by Bridgit *et al.*(1996). Anitha and Mathew (2010) reported that green manuring in wet seeded rice with intercropped dhaincha enhanced rice yield than growing wet seeded rice alone without green manure.

Cost and return :

Cost of cultivation varied depending on the different method of rice cultivation which include seed rate, nursery cost, planting by manual / machine, direct seeding by seed drill including of green manure as intercropping and it incorporation (Table 4).

Sowing of rice with paddy drum seeder without any green manure intercropping fetched with lower cost of cultivation of Rs. 32283 and 33485 / ha, it save the cost of 33.29 and 32.84 per cent as against manual planting and 13.99 and 14.22 per cent as against machine transplanting methods during the tow years of experiments. This was achieved by avoiding the cost incurred for nursery preparation, pulling out of seedlings and transplanting etc.

Whereas higher gross income of Rs. 94, 239 and 97962 /ha were realized with the treatment of rice planting at 25x25 cm + dhaincha intercropping and its incorporation at 30 DAS. However, the higher net income

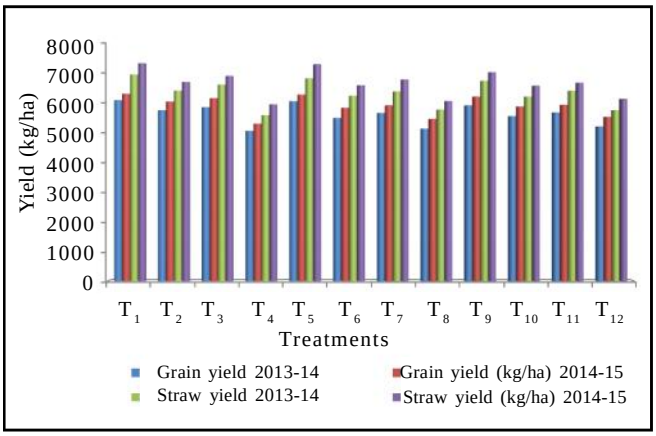

Fig. 1: Effect of different rice establishment method and co-cocultivation of green manure on rice yield and yield attributes (kg/ ha)

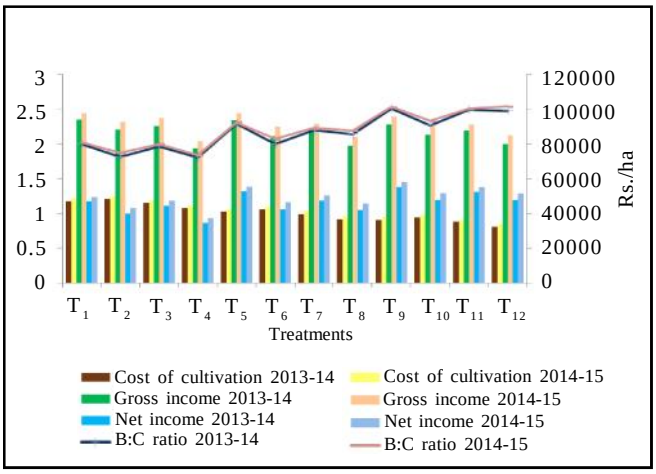

Fig. 2: Effect of different rice establishment method and co- cocultivation of green manure on economics

Table 4: Effect of different rice establishment method and co-cultivation of green manure on economics

Treatments	Cost of cultivation (Rs./ha)		Gross income (Rs./ha)		Net income (Rs./ha)		B:C ratio	
	2013-14	2014- 15	2013-14	2014- 15	2013-14	2014- 15	2013-14	2014- 15
T_1	47181	48575	94239	97962	47058	49387	2.00	2.02
T_2	48483	49824	88527	92934	40044	43110	1.82	1.87
T_3	45981	47502	90417	94983	44436	47481	1.97	2.00
T_4	43031	44483	77718	81714	34687	37231	1.81	1.84
T_5	40950	42400	93774	97800	52824	55400	2.29	2.31
T_6	42277	43598	84597	90036	42320	46438	2.00	2.07
T_7	39752	41182	87315	91665	47563	50483	2.20	2.23
T_8	36802	38346	78876	83955	42074	45609	2.14	2.19
T_9	36433	37831	91521	95898	55088	58067	2.51	2.53
T_{10}	37735	38850	85527	90594	47792	51744	2.27	2.33
T_{11}	35233	36466	87621	91524	52388	55058	2.49	2.51
T_{12}	32283	33485	79959	85065	47676	51580	2.48	2.54

of Rs.55088 and 58067 / ha was achieved when the rice was sown directly by using paddy cum dhaincha seed drill and incorporation of intercropped dhaincha on 30 DAS (T_9). Gross income and net income were low when the rice was planted either manual or machine without intercropping green manure. The higher B:C ratio ranged from 2.27 to 2.51 for per rupee invested was realized when the rice sown directly in the main field by using paddy cum dhaincha seed drill or paddy seed drum. But it was comparable with rice planting at 25 x 25 cm + dhaincha intercropping and its incorporation at 30 DAS during both the years of studies.

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