Maximizing productivity and profitability of rice through crop establishment methods and weed management practices in winter rice-garden pea relay cropping system

ABSTRACT

A field experiment was conducted at the farmer's field at Pirakata Brahmin Gaon under the jurisdiction of Krishi Vigyan Kendra, Jorhat to study resource conservation through crop establishment methods and weed management practices in winterrice(*Oryza sativa*. L.)-garden pea *(Pisum sativum* var. *hortense*) relay cropping system during 2019-20 & 2020-21. The treatment consisted of fourcrop establishment methods of winter rice (T) *viz.*, T_1: WDSR (Broadcasting), T_2: WDSR(Modified Drum Seeder with furrow opener), T_3: PTR (Farmers' Practice), T_4: PTR (Mechanized Transplanting by paddy transplanter) where WDSR: Wet Direct Seeded Rice, PTR: Puddled Transplanted Rice along with three weed management practices of rice (W) *viz.*, W_0: Weedy check, W_1: Pretilachlor 0.75 kg/ha as pre-emergence fb bispyribac-sodium 0.025 kg/ha (20 DAS/DAT) as post-emergence, W_2: Pretilachlor 0.75 kg/ha as pre-emergence fb manual weeding (30 DAS/DAT). The experiment was laid out in a factorial randomized block design with three replications. The soil of the experimental site was sandy clay loam in texture, medium acidic in reaction, medium in organic carbon and available N and low in available P_2O_5 and K_2O.The study revealed that the establishment method that T_2, $T_3$and T_4had higher growth and yield parameters of the crop as compared to T_1: WDSR (B) which resulted in higher grain and straw yield of winter rice as well as uptake of nutrients. The highest grain yield of 49.79 and 50.13 q/ha of winter rice was recorded under T_4: PTR (MTR) followed by 46.62 and 47.8q/ha in T_2: WDSR (Drum seeder) during 2019 and 2020, respectively. The percent increase in grain yield of winter rice in $W_1$and W_2as compared to W_0(control) was 82.97, 84.52 in 2019 and 81.62, 81.58, respectively in 2020. The treatment combination T_4W_2recorded the highest grain and straw yield ofwinterricewhich was statisticallyat parwith T_4W_1, T_2W_1 and T_2W_2. ThehigherB:C of 2.27 and 2.14 was recorded in $T_2W_1$with higher gross return and net return followed by T_2W_2(2.18 and 2.08 during 2019 and 2020, respectively).

Keywords: Drum seeder, Economics, Growth, Integrated weed management, Rice, Yield.

INTRODUCTION

Agriculture is essential in India, with rice serving as the primary staple. With a yearly output of 90 Mt and 45 Mha, it is the world's second-largest producer (Singh *et al.* 2013). Rice is essential to Indian and Assamese society, providing food security and livelihoods. Population growth and dietary changes will drive up demand for rice (Joshi *et al.* 2009). However,transplanting rice is a costly and labor-intensive process, causing scarcity of labor, uncertain irrigation water supply, groundwater depletion, and rising production costs. In the changing climate scenario, there is an alternative option for rice cultivation through an alternative establishment method called DSR. Direct seeding rice, a common practice before the green revolution in India, is becoming popular due to its potential to save water and labor. Direct Seeded Rice (DSR) is an efficient, water-labor, and energy-efficient alternative to conventional puddled transplanted rice, offering promising results in resource conservation. Direct seeding can resolve edaphic conflicts between rice and non-rice crops, enhancing sustainability in the rice-based cropping system. However, weed infestation poses a threat to yield and DSR expansion. The profitability of rice-based cropping could be increased with minimal tillage, providing adequate herbicide control (Pradhan *et al.* 2022).In the face of shrinking agricultural land, shortage of irrigation water, and labor shortages, adopting improved rice varieties with higher water productivity and modern agronomic technology is crucial to meet global rice demand. (Leeper, 2010). The DSR method of establishment reduces total labor requirements by 11-66% compared to puddled transplanted rice (PTR), allowing faster and easier planting (Singh *et al.,* 2006). DSR improves soil health, emits less methane, and ensures higher profit in areas with assured irrigation supply (Kumar *et al.,* 2016). Weeds are a major cause of yield loss in DSR and low-land transplanted conditions, causing yield loss of 17-24%. Weed management practices under DSR systems may vary depending on socio-economic conditions and other factors. Integrated approaches through mechanical and chemical control may be an economical method(Chatterjee *et al.,* 2016). In Assam, Garden Pea is a promising pulse crop with wide adaptability and high production potential. Winter rice-garden pea relay cropping is common in Assam, potentially earning additional economic benefits and doubling farmers' income. The inclusion of pulses in rice-based cropping systems enhances crop intensification, diversity, and weed control (Pradhan *et al.* 2022).All the above facts have highlighted the need to reconsider crop establishment methods and weed water, and nutrient management measures in a system approach for increased rice output(Sharma *et al.* 2020 and Pradhan *et al.* 2021).Keeping the above facts in mind, a field experiment on crop establishment methods and weed management practices in

the winter rice-relay garden pea sequence was planned to analyze the impact of crop establishment methods and weed management practices on the productivity and profitability of rice.

MATERIALS AND METHODS

A field experiment was undertaken to study the "Resource conservation through crop establishment methods and weed management practices in winter rice (*Oryza sativa* L.) - garden pea (*Pisum sativum* var. *hortense*) relay cropping system" during *kharif-rabi* season. The two-year experiment was carried out during the years 2019-20 and 2020-21 in the farmers‟ (Mr. Dipen Borkotoki) field located at Vill.-PirakataDakhin Brahman gaon, P.O.-Pirakata, Dist.- Jorhatunder Upper Brahmaputra Valley Zone of Assam which is located at 26°785857'N latitude and 94°389172'E longitude and an elevation of 86.6 m above the mean sea level.The climate of Jorhat is sub-tropical humid with hot summer and cold winter. Monsoon normally sets in the month of June and continues up to the month of September-October with pre-monsoon showers from mid-March to April. Theexperimentwaslaidoutinafactorial randomized blockdesign with 3 replications.Thus,twelvetreatmentcombinationsineachreplicationwitha total of thirty-six plots were tested. The treatment consisted of four crop establishment methods of winter rice (T) *viz.*, T_1: WDSR (Broadcasting), T_2: WDSR (Modified Drum Seeder with furrow opener), T_3: PTR (Farmers' Practice), T_4: PTR (Mechanized Transplanting by paddy transplanter) where WDSR: Wet Direct Seeded Rice, PTR: Puddled Transplanted Rice along with three weed management practices of rice (W) *viz.*W_0: Control (No weed Control), W_1: Pretilachlor @ 0.75 kg/ha as pre-emergence fb Bispyribac-sodium 0.025 kg/ha (20 DAS/DAT) as post-emergence, W_2: Pretilachlor 0.75 kg/ha as pre-emergence fb manual weeding (30 DAS/DAT). The soil of the experimental site was sandy clay loam in texture, medium acidic in reaction, medium in organic carbon and available N and low in available P_2O_5 and K_2O.In the first year and 2nd year of field experimentation, the total amount of rainfall received was 1296.3 and 1130.2 mm.The weekly mean maximum temperature ranged from 25.8 to 34.8 and 22.0 to 29.0°C during the growing period of rice.

In winter rice: during land preparation, FYM 3 t/ha was applied. Fertilizers were applied in the form of urea, single super phosphate (SSP) and muriate of potash (MOP) as per the recommended dose of 60-20-40 kg/ha as N, P_2O_5 and K_2O for winter rice. Nitrogen was applied in 3 split doses *i.e.*, ½ of N was applied in final ploughing, ¼ at active tillering stage and remaining ¼ at panicle initiation stage. All the phosphatic and potassic fertilizers were

applied well ahead of sowing/transplanting. Nofertilizerwasappliedtotherelaygardenpea. For winter rice sowing was done on 26th Juneand 28th June (2019 & 2020,respectively) @ 40 kg/ha of seeds in the nurserybed for manual transplanting as well as in mat nursery (seed tray) for mechanical puddled transplanting of rice (MPTR), 75 kg/ha of seeds under WDSR (Broadcasting) and 30 kg/ha for WDSR by drum seeder in the main field. Eighteen days old seedlings from mat nursery were transplanted by transplanter under the treatment PTR(MTR) and twenty-one days old seedlings were thereafter transplanted manually i.e haphazardly which is commonly practiced by farmers in the main field under transplanting under PTR (FP).For drum seeder the row-to-rowspacingwas 20 cm (Fixed) and plant-to-plant was adjusted to 10 cm. Row to row spacing for transplanter was 30 cm (Fixed) and plant to plant was adjusted to 10 cm. Inrespectofrelaygardenpeas,therewere no treatmentsimposed.Onlythe seeds are broadcasted @ 60 kg/ha 15 days afterflowering of winter rice. In the case of Gardenpea, no tillage operation was done as sowing of the garden pea as a relay crop was done in standing crop of winter rice 15 days after flowering No. additional inputs like fertilizers were added to garden pea. The varieties used for rice and garden pea areRanjit Sub-1 & Azad Pea-3 (AP-3) respectively. The field was ploughed thoroughly with tractor and power tiller. Theland was puddled and levelled for layingout the experiment. For mechanical and manual transplanting of winter rice, treatment-wise plots were puddled again by hand hoe and levelled.Garden pea variety Azad Pea-3 was sown at the seed rate of 60 kg/ha 15 days after flowering of winter rice. Broadcasting of seeds was done manually.As per treatment, pretilachlor (Rifit 50% EC) 0.75 kg/ha, as pre-emergence herbicide was applied with 3 DAS of direct seeding and broadcasting and 3 DAT oftransplantedrice.Aspertreatment,bispyribac-sodium(NomineeGold10%SC)0.025 kg/ha (20 DAS/DAT)was applied as post-emergence. Herbicides were sprayed with knapsack sprayer fitted with flat fan nozzle. Noherbicideorweedingoperationwasdoneingardenpea.Integratedweedmanagement:As per treatment, one manual weeding was done at 30 DAS/DAT subsequenttothe applicationofrecommendedherbicide*i.e.*pretilachlor(Rifit50%EC) 0.75 g/ha aspre-emergence herbicide.Necessary plant protection measures have been taken as per need in both crops.The study analysed Yield and yield parameters i.e. the number of panicles, panicle length, total, filled, and unfilled grains per panicle, 1000-grain weight, grain yield, and straw yield in a net plot area. The total panicles were counted in two randomly selected areas of 1m x 1m, and the average values were calculated. The weight of the harvested crop was then threshed manually, and the weight of the straw was calculated by subtracting the grain weight from the total weight of the bundle. Gross return per hectare was calculated using minimum support

price and market price of inputs, and net monetary returns were calculated by subtracting cultivation costs.Benefit-costratiowascomputeddividingthenetreturnbytotalcostof cultivation. All the recorded data were analysed by ANOVA technique applicable to the factorial RBD. Here the study of treatments on rice is mainly focussed though details of the materials and methods of both the crops have been discussed earlier.

RESULT & DISCUSSION

Effect of establishment methods on yield attributes of rice: The details of the data on yield attributes of rice have been mentioned in Tables No. 1 and 2. A significantly higher number of panicles / m^2 was found in WDSR (Drum seeder) in both years and was followed by PTR (MTR).PTR(MTR) showed significantly higher panicle length, number of grains/panicle, and number of filled grains/panicle than all other treatments except PTR(FP) during 2019 but PTR(MTR) showed significantly higher panicle length over WDSR (Broadcasting) but statistically at par with rest of the treatments *i.e* WDSR (Drum seeder) and PTR(FP) during the second year. This might be due to proper spacing management, plant population and favorable growth conditions of the crop from the early vegetative stage to the reproductive stage. Besides, the crop was helped by less crop weed competition.WDSR (Drum seeder) manages the proper spacing and early crop establishment which results in proper plant growth, increased tiller no and higher grain yield as compared to improper spacing. Proper spacing also ensures good water management, increased photosynthetic activities as well and assimilated partitioning (Kundu *et al.* 1993, Baloch *et al.* 2002), thereby resulting in good yield in well-spaced rice fields.Crop establishment methods failed to show significant variation in the number of unfilled grains per panicle and 1000-grain weight in both years of experimentation. Also recorded maximum yield attributing characters like panicle length, filled grains/panicle and 1000 grain weight, may be due to better resource availability like space, sunlight, nutrients, water and air due to low weed competition. Crop establishment methods failed to record any significant difference concerning 1000 grain weight in both years of experimentation.The highest grain yield of 49.79 q/ha and 50.13 q/ha was recorded under PTR (MTR) but remained statistically at par with WDSR (Drum seeder) i.e 46.62 q/ha and 47.68 q/ha during 2019 and 2020, respectively. The crop establishment methods significantly influenced the grain yield of winter rice in both years. The highest grain yield of 49.79 q/ha and 50.13 q/ha was recorded under PTR(MTR) but it was statistically at par with WDSR(Drum seeder) producing 46.62 q/ha and 47.68 q/ha during 2019 and 2020 respectively. Better weed control resulting better crop growth parameters under the crop

establishment methods *viz.* PTR (MTR), WDSR (Drum Seeder) and PTR(FP) as compared to WDSR(Broadcasting) could have caused better yield attributes and finally grain yield. Similar findings were also reported by Das *et al* (2014) and Kundu *et al* (1993).During both years of study, the highest values for straw yields of 60.39 and 58.88q/ha were registered under puddled transplanting (mechanical transplanting by paddy transplanter). However, this treatment was statistically at par with WDSR (Drum seeder) concerningthe straw yield of winter rice. Significantly higher biological yield (112.41 and 110.30 q/ha) was recorded under PTR (MTR) over other treatments in 2019 and 2020, respectively. Apart from that WDSR (Drum seeder) i.e. 104.91 and 105.50 q/ha, showed significant differences over PTR (FP) and WDSR (Broadcasting) in both the years of study. Crop establishment methods of rice failed to show significant influence on the harvest index of winter rice in both years of investigation.

Effect of weed management practices on yield attributing characters:Weed management practices *i.e* Pretilachlor 0.75 kg/ha as pre-emergence fb bispyribac-sodium 0.025 kg/ha (20 DAS/DAT) as post-emergence recorded significantly higher panicle number over weedy check and remained at par with pretilachlor 0.75 kg/ha as pre-emergence fb manual weeding (30 DAS/DAT) during 2019 are presented in Table 1 and 2. But during 2020, pretilachlor 0.75 kg/ha as pre-emergence fbmanual weeding (30 DAS/DAT) recorded significantly higher panicle numbers than weedy check followed by Pretilachlor 0.75 kg/ha as pre-emergence fb bispyribac-sodium 0.025 kg/ha (20 DAS/DAT) as post-emergence.Highest number of grains per panicle, and number of filled grains per panicle recorded in pretilachlor 0.75 kg/ha as pre-emergence fb bispyribac-sodium 0.025 kg/ha (20 DAS/DAT) as post-emergence which was at with pretilachlor 0.75 kg/ha as pre-emergence fb manual weeding (30 DAS/DAT) in both the years of experimentation. The higher number of panicles/m2 in weed management practices might be due to higher weed control efficiency and weed control index during the whole crop growth period mainly early vegetative stage to the critical crop weed competition period which could have facilitated proper vegetative and reproductive growth of the crop. Singh et al (2005) also reported a similar type of experimental findings.Weed management practices did not produce any significant difference in panicle length (cm), number of unfilled grains/panicle and 1000-grain weight in both the years of study Theweedmanagementtreatmentsalsoshowednosignificantvariationwithrespecttothe1000-grain weight. Similarresults werereported byKumar*et al.* (2015).No significant difference was observed between pretilachlor 0.75 kg/ha as Pre-emergence fb bispyribac-sodium 0.025 kg/ha

(20 DAS/DAT) as post-emergence (45.03 q/ha, 45.16 q/ha) and pretilachlor 0.75 kg/ha as Pre- emergence fb manual weeding (30 DAS/DAT) (44.20 q/ha and 45.18 q/ha) in respect of grain yield of winter rice but both showed significantly higher grain yield over weedy check in both the years. Significant differences on straw yield of winter rice were observed due to different crop establishment methods during both the years of experimentation. Pretilachlor 0.75 kg/ha as pre-emergence fb bispyribac-sodium 0.025 kg/ha (20 DAS/DAT) as post-emergence recorded significantly higher straw yield (54.13 and 52.98 q/ha, respectively) over weedy check during 2019 and 2020 but statistically at par with pretilachlor 0.75 kg/ha as pre-emergence fb manual weeding (30 DAS/DAT)The biological yield of winter rice recorded in plots treated with pretilachlor 0.75g/ha as pre-emergence fb bispyribac-sodium 0.025 kg/ha (20 DAS/DAT) as post-emergence remained statistically at par with pretilachlor 0.75 kg/ha as pre-emergence fb manual weeding (30 DAS/DAT) during both the years and remained significantly higher than weedy check during 2019 and 2020, respectively but Weed management practices failed to show significant effect on harvest index of winter rice. However, the pre-emergence application of pretilachlor 0.75 kg/ha fb manual weeding at 30 DAS/DAT recorded higher harvest index in both years.

Effect of interaction: Combination of WDSR (Drum seeder) and pretilachlor 0.75 kg/ha as pre-emergence fb manual weeding (30 DAS/DAT) recorded significantly higher panicle number/m2 during 2019 (Table 3). No significant interaction was observed during 2020.No significant interaction effect of crop establishment methods and weed management practices on panicle length, number of grains/panicle, number of filled grains/panicle, unfilled grains per panicle and 1000-grain weight of rice in both the years of investigation.With respect to grain yield, there was no significant interaction effect during 2019 but significant interaction during 2020. Treatment combination of PTR (MTR) with pretilachlor 0.75 kg/ha as pre-emergence fb manual weeding (30 DAS/DAT) showed significantly higher grain yield than other treatment combinations but at par with treatment combination of WDSR (Drum seeder) and pretilachlor 0.75 kg/ha as pre-emergence fb bispyribac-sodium 0.025 kg/ha (20 DAS/DAT) as post-emergence; WDSR (Drum seeder) with pretilachlor 0.75 kg/ha as pre-emergence fb manual weeding (30 DAS/DAT) and PTR (MTR) with pretilachlor 0.75 kg/ha as pre-emergence fb bispyribac-sodium 0.025 kg/ha (20 DAS/DAT) as post-emergence in both the years of investigation.In terms of straw yield of winter rice, combination of PTR (MTR) with pretilachlor 0.75 kg/ha as pre-emergence fb manual weeding (30 DAS/DAT) i,e (63.35 and 62.39 q/ha, respectively) showed significantly higher straw yield of winter rice

than other treatment combinations but at par with treatment combination of WDSR (Drum seeder) and pretilachlor 0.75 kg/ha as pre-emergence fb bispyribac-sodium 0.025 kg/ha (20 DAS/DAT) as post- emergence; WDSR (Drum seeder) with pretilachlor 0.75 kg/ha as pre-emergence fb manual weeding (30 DAS/DAT) and PTR(MTR) with pretilachlor 0.75 kg/ha as pre-emergence fb bispyribac-sodium 0.025 kg/ha (20 DAS/DAT) as post- emergence in both the years of experimentation.

Grainyield(q/ha): Data on grain yield of winter rice as influenced by different crop establishment methods and weed management practices are presented in Table 4.

Crop establishment method of rice: The crop establishment methods significantly influencedthegrainyieldofwinterriceinbothyears.Thehighestgrainyieldof 49.79 q/ha and 50.13 q/ha was recorded under PTR(MTR) but it was statistically at par with WDSR(Drum seeder) producing 46.62 q/ha and 47.68 q/ha during 2019 and 2020 respectively. Better weed control resulting better crop growth parameters under the crop establishment methods *viz.* PTR (MTR), WDSR (Drum Seeder) and PTR(FP) as compared to WDSR(Broadcasting) could have caused better yield attributes and finally grain yield. Similar findings were also reported by Das *et al* (2014) and Kundu *et al* (1993) and Pradhan *et al (2022).* Das *et al* (2019) in UP also reported a similar trend in yield-attributing characters.

Weed management: In both years of experimentation, weed management practices showed significant differences on the grain yield of winter rice. No significant differencewasobservedbetweenpretilachlor 0.75kg/ha aspre-emergence fb bispyribac-sodium 0.025 kg/ha(20DAS/DAT)aspost-emergence(45.03q/ha,45.16q/ha)andpretilachlor 0.75 kg/ha as pre-emergence fb manual weeding (30 DAS/DAT) (44.20 q/ha and 45.18 q/ha) but both showed significantly higher grain yield over weedy check in both the years. Significant influence on winter rice growth parameters by both the weed management treatments compared to weedycheck, resulted into enhanced synthesis and translocation of photosynthates. This resulted in increased yield attributes *viz.* numberof panicles/m^2, panicle length and number of grains/panicle which ultimately increased grain yield under thesetreatments. As compared to the weedycheck, effective weed control by these treatments might have helped to conducive environment for overall better growth and development of winter rice. Kundu*et al* (1993), Gopinath *et al*. (2013), Govindan and Chinnusamy(2014) also reported similar type of findings.

Interaction effect: In respect of grain yield there was no significant interaction effect during 2019 but recorded significant interaction during 2020 (Table 5). The treatment

combinationofPTR(MTR)withpretilachlor0.75kg/haaspre-emergencefbmanual weeding (30 DAS/DAT) showed significantly higher grain yield than other treatment combinations but at par with treatment combination of WDSR (Drum seeder) and pretilachlor 0.75 kg/ha as pre-emergence fb bispyribac-sodium 0.025 kg/ha (20 DAS/DAT) as post-emergence; WDSR (Drum seeder) with pretilachlor 0.75 kg/ha as pre-emergencefbmanualweeding(30DAS/DAT)andPTR(MTR)withpretilachlor @ 0.75 kg/ha as pre-emergence fb bispyribac-sodium 0.025 kg/ha (20 DAS/DAT) as post- emergence in both the years of investigation.

Straw yield:

Crop establishment method of rice: The effect of crop establishment methods on the straw yield of winter rice was found to be statistically significant in both the years of investigation as described in Table 4. The highest value for straw yields of 60.39 and 58.88 q/ha was registered under PTR (MTR). However, this treatment was statistically at par with WDSR (Drum seeder) with respect tothe straw yield of winter rice. Further perusal of data showed that different crop establishment methods that recorded less weed infestation resulted in significant enhancement in rice growth parameters *viz.*, dry matteraccumulation and total tillers per $m^{2,}$etc as well as nutrient uptake which might be the reason for increased straw yield of winter rice in these crop establishment treatments as compared to WDSR (Broadcasting) in which there was more intensive menace of weed.

Weed management: A significant difference in the straw yield of winter rice was observed due to different crop establishment methods during both years of experimentation (Table 4). Pretilachlor 0.75 kg/ha as pre-emergence fb bispyribac-sodium 0.025 kg/ha (20 DAS/DAT) as post-emergence recorded significantly higher straw yield (54.13 and 52.98 q/ha,respectively) overweedycheck during 2019 and 2020 butit was statistically at par with pretilachlor 0.75 kg/ha as pre-emergence fb manual weeding (30DAS/DAT). This might be due to the effective clampdown of weeds by weed management practices resulting in higher dry matter accumulation, total tillers per m^2 and nutrient uptake by winter rice which eventually increased straw yield. Subramanian *et al* (2006) and Surin *et al.* (2013) also drew similar conclusions.

Interaction effect: The interaction effect of crop management methods and weed management on the straw yield of winter rice was found to be statistically significant during 2019 and 2020. The data are shown in Table 6.A close evaluation of data revealed that the

interaction effect of PTR(MTR) with pretilachlor 0.75 kg/ha as pre-emergence fb manual weeding (30 DAS/DAT) *i,e* gave significantly higher straw yield(63.35 and 62.39 q/ha, respectively) of winter rice than other treatment combinations but at par with treatment combination of WDSR (Drum seeder) and pretilachlor 0.75 kg/ha as pre-emergence fb bispyribac-sodium 0.025 kg/ha (20 DAS/DAT) as post-emergence, WDSR (Drum seeder) with pretilachlor 0.75 kg/ha as pre-emergence fb manual weeding (30 DAS/DAT) and PTR(MTR) with pretilachlor 0.75 kg/ha as pre-emergence fb bispyribac-sodium 0.025 kg/ha (20 DAS/DAT) as post-emergence in both the years of experimentation

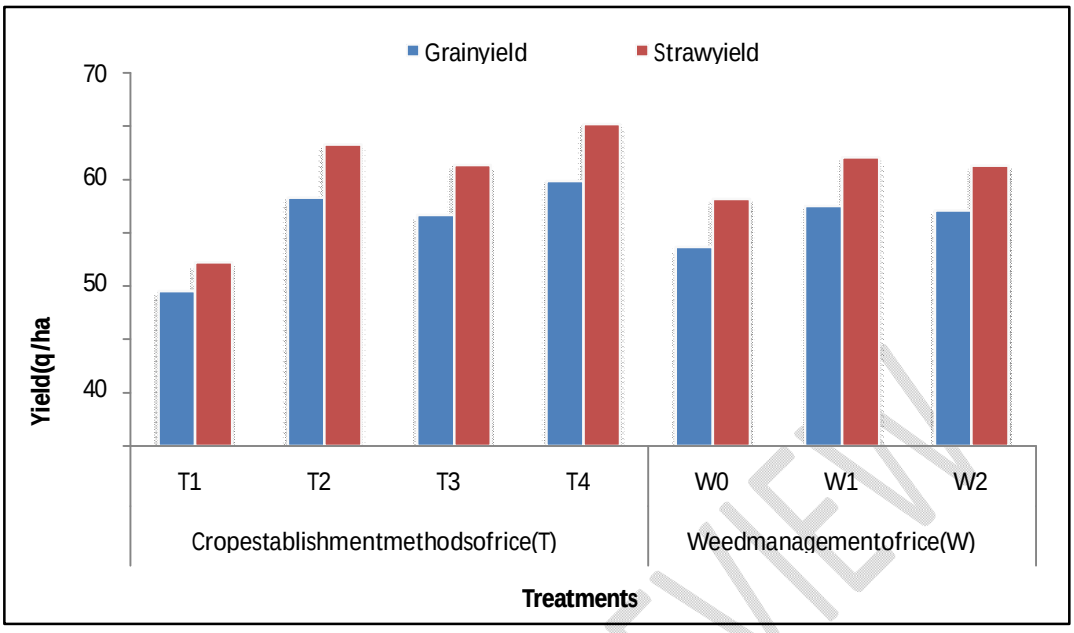

Fig.1.Effectofestablishmentmethodandweedmanagementongrainyieldand straw yield of winter rice (2019)

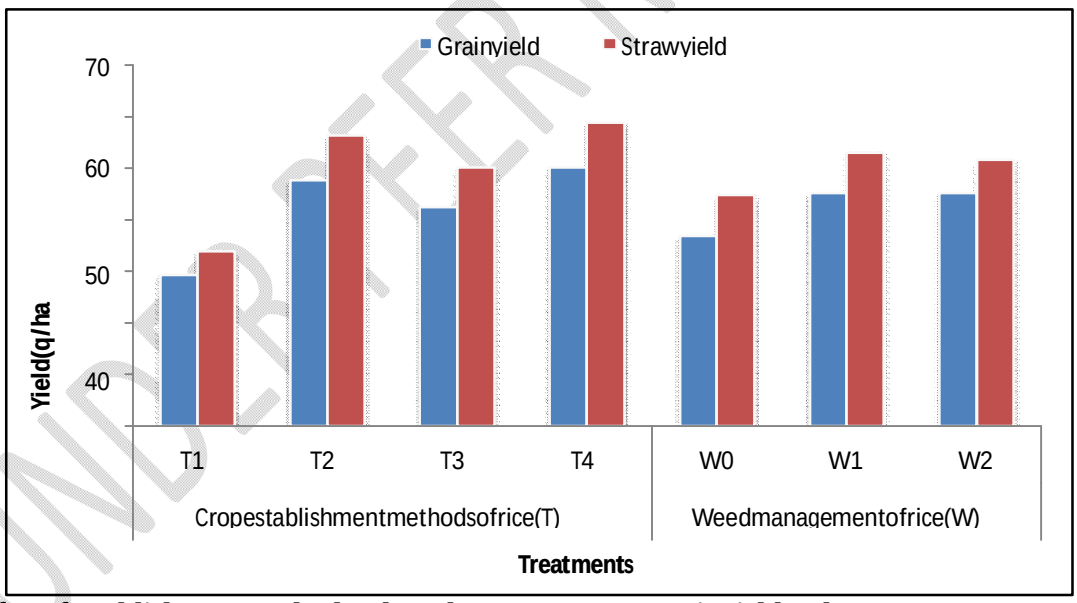

Fig.2.Effectofestablishmentmethodandweedmanagementongrainyieldand straw yield of winter rice (2020)

Effect of treatments on economics: A close evaluation of data revealed that a treatment combination of PTR (FP) and pretilachlor 0.75 kg/ha as pre-emergence 0.75 kg/ha as pre-emergence fb manual weeding (30 DAS/DAT) recorded highest cost of cultivation in both the years of investigation (Table-7). More man-days required for transplanting and manual weeding resulted in higher cost of cultivation of winter rice. The treatment combination of

PTR (MTR) and pretilachlor 0.75 kg/ha as pre-emergence 0.75 kg/ha as pre-emergence fb manual weeding (30 DAS/DAT) recorded the highest gross return in both the years of study. In respect of net return, treatment combination of WDSR (Drum seeder) and pretilachlor 0.75 kg/ha as pre-emergence 0.75 kg/ha as pre-emergence fb bispyribac-sodium 0.025 kg/ha (20 DAS/DAT) as post-emergence recorded higher NR (Rs. 88,960 and Rs. 88,365/ha during 2019 and 2020, respectively). The highest B-C ratio was recorded under treatment combination of WDSR (Drum seeder) and pretilachlor 0.75 kg/ha as pre-emergence 0.75 kg/ha as pre-emergence fb bispyribac-sodium 0.025 kg/ha (20 DAS/DAT) as post-emergence (2.27 and 2.14, respectively) in 2019 and 2020 which was closely followed by WDSR (Drum seeder) and pretilachlor 0.75 kg/ha as pre-emergence pretilachlor 0.75 kg/ha as pre-emergence 0.75 kg/ha as pre-emergence fb manual weeding (30 DAS/DAT) i.e. 2.12 and 2.02 in 2019 and 2020, respectively. Bhuvaneswari (1998), Narasimman (2000), Kumar *et.al.*(2018) also reported similar type of findings from their study. More man-days required for transplanting and manual weeding resulted in higher cost of cultivation of winter rice which influenced the system cost of cultivation. The higher cost of cultivation and net returns as well as B-C ratio under aforesaid treatments was unswervingly endorsed to the resultant upsurge in yield of the crops in the system.

Conclusions

Based on the two years study in winter rice–garden pea relay cropping system, rice establishment method wet direct seeded rice (WDSR) with drum seeder in combination with weed management practice i.e pretilachlor 0.75 kg/ha as pre-emergence fb either bispyribac - sodium 0.025 kg/ha at 20 DAS or manual weeding at 30 DAS is ideal to achieve better system profitability (B:C) in *rainfed* areas of Assam.

version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology

Details of the AI usage are given below:

1.

2.

3.

Reference:

Surajyoti Pradhan, L.M. Garnayak, K.N. Mishra, R.K. Panda, M.M. Mishra, & R.P. Meena. (2021). Effect of conservation tillage and weed management practices in rice - sweet corn - cow pea cropping system on growth, yield and economics of rice in coastal Odisha. *Annals of Agricultural Research*, *42*(4), 362-365.

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Table 1: Effect of establishment method and weed management on number of panicles, panicle length of winter rice, 2019

Parameters → Treatment ↓	Number of panicles/m^2	Panicle length (cm)	Number of Grains/panicles	Number of filled grains/panicles	Number of unfilled grains/panicles	1000-grain weight (g)
Crop establishment methods of rice (T)						
T_1:WDSR (Broadcasting)	193.78	13.33	91.52	78.70	13.26	22.73
T_2: WDSR (Modified Drum Seeder with furrow opener)	323.22	21.91	146.04	132.85	13.19	23.47
T_3 PTR (Farmers' Practice)	265.85	22.80	148.81	135.74	13.07	23.26
T_4: PTR (Mechanized Transplanting by paddy transplanter)	298.04	23.03	152.81	139.63	12.81	23.66
SEm (±)	5.67	0.36	3.64	3.59	0.30	0.41
CD(P=0.05)	16.62	1.05	10.67	10.53	NS	NS
Weed management of rice (W)						
W_0 : Weedy check	236.64	19.86	125.86	112.81	13.06	22.75
W_1 :: Pretilachlor 0.75 kg/ha as pre-emergence fb Bispyribac-sodium 0.025 kg/ha (20 DAS/DAT) as post-emergence	288.33	20.32	139.78	126.81	12.97	23.30
W_2 : Pretilachlor 0.75 kg/ha as pre-emergence fb manual weeding (30 DAS/DAT)	285.69	20.62	138.75	125.58	13.22	23.79
SEm (±)	4.91	0.31	3.15	3.11	0.26	0.35
CD(P=0.05)	14.40	NS	9.24	9.12	NS	NS
Interaction (T x W)						
SEm (±)	9.82	0.62	6.30	6.22	0.51	0.71
CD(P=0.05)	28.80	NS	NS	NS	NS	NS

WDSR: Wet Direct Seeded Rice, PTR: Puddled Transplanted Rice. DAS: days after sowing, DAT: Days after transplanting, NS: Non-significant

Table2:Effectofestablishmentmethodandweedmanagementonnumberofpanicles,paniclelengthofwinterrice,2020

Parameters→ Treatment ↓	Number of panicles/m^2	Panicle length(cm)	Number of Grains/panicle	Numberof filled grains/panicle	Numberof unfilled grains/panicle	1000-grain weight (g)
Cropestablishmentmethodsofrice (T)						
T_1:WDSR(Broadcasting)	198.89	12.61	96.76	83.61	13.41	22.69
T_2:WDSR(ModifiedDrumSeederwith furrowopener)	313.11	22.41	150.20	137.20	13.00	23.25
T_3:PTR(Farmers'Practice)	266.52	22.85	154.09	140.80	13.30	23.03
T_4:PTR(MechanizedTransplanting by paddytransplanter)	300.59	22.96	156.54	143.43	13.11	23.37
SEm(±)	5.79	0.48	3.42	3.50	0.28	0.48
CD(P=0.05)	16.98	1.41	10.04	10.26	NS	NS
Weedmanagementofrice(W)						
W_0: Weedycheck	243.47	20.02	133.03	120.00	13.11	22.70
W_1:: Pretilachlor0.75kg/ha aspre-emergencefbBispyribac-sodium0.025kg/ha (20DAS/DAT)as post-emergence	282.83	20.31	144.36	131.06	13.33	23.23
W_2: Pretilachlor0.75kg/haaspre-emergence fbmanualweeding(30 DAS/DAT)	283.03	20.29	140.81	127.72	13.17	23.33
SEm(±)	5.01	0.42	2.96	3.03	0.24	0.42
CD(P=0.05)	14.70	NS	8.69	8.89	NS	NS
Interaction(TxW)						
SEm(±)	10.03	0.83	5.93	6.06	0.48	0.84
CD(P=0.05)	NS	NS	NS	NS	NS	NS

WDSR:WetDirectSeededRice,PTR:PuddledTransplantedRice.DAS:daysaftersowing,DAT:Daysaftertransplanting,NS:Non-significan

Table 3: Interaction effect of establishment method and weed management on panicles/m^2 in winter rice 90 DAS

Weed Management	Establishment method			
	2019			
	T_1	T_2	T_3	T_4
W_0	190.11	271.78	216.56	268.11
W_1	200.89	341.67	296.78	314.00
W_2	190.33	356.22	284.22	312.00
SEm (±)	9.82			
CD(P=0.05)	28.80			

Table 4: Effectofestablishment methodandweedmanagementongrainyieldandstrawyieldofwinterrice

	Grain yield((q/ha))		Straw yield (q/ha)	
Treatment ↓	**2019**	**2020**	**2019**	**2020**
Cropestablishmentmethodsofrice (T)				
T_1:WDSR(Broadcasting)	29.04	29.32	34.43	33.87
T_2:WDSR(ModifiedDrumSeederwithfurrow opener)	46.62	47.68	56.51	56.38
T_3:PTR(Farmers'Practice)	43.34	42.47	52.73	50.13
T_4:PTR (Mechanized Transplantingbypaddytransplanter)	49.79	50.13	60.39	58.88
SEm(±)	1.06	0.89	0.99	1.06
CD(P=0.05)	3.12	2.60	2.88	3.10
Weedmanagementofrice(W)				
W_0: Weedycheck	37.36	36.86	46.34	44.81
W_1:: Pretilachlor0.75kg/ha as pre-emergencefbBispyribac-sodium0.025	45.03	45.16	54.13	52.98
W_2: Pretilachlor0.75kg/haaspre-emergencefb manualweeding(30	44.20	45.18	52.58	51.65
SEm(±)	0.92	0.77	0.86	0.91
CD(P=0.05)	2.70	2.25	2.51	2.68
Interaction(TxW)				
SEm(±)	1.84	1.54	1.71	1.83
CD(P=0.05)	NS	4.51	5.02	5.37

CD(P=0.05)	9.29	10.13

Table 5: Interaction effect of establishment method and weed management on grain yield (q/ha) of winterrice, 2020

Weed Management	Establishment method			
	2020			
	T_1	T_2	T_3	T_4
W_0	27.68	39.17	36.76	43.85
W_1	30.57	52.76	46.00	51.30
W_2	29.71	51.10	44.65	55.25
SEm (±)	1.54			
CD(P=0.05)	4.51			

Table 6: Interaction effect of establishment method and weed management on straw yield (q/ha) of winterrice

Weed Management	Establishment method							
	2019				2020			
	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4
W_0	34.50	47.14	47.89	55.84	33.65	47.60	42.96	55.05
W_1	35.49	62.82	56.23	61.97	35.08	62.40	55.25	59.18
W_2	33.30	59.58	54.09	63.35	32.87	59.15	52.18	62.39

SEm (±)	1.71	1.83
CD(P=0.05)	5.02	5.37

Table 7: Gross cost, gross return, net return and B: C of winter rice for different treatments

	Parameters →	Gross cost (Rs/ha)		Gross return (Rs/ha)		Net return (Rs/ha)		B-C ratio	
	Treatment combination↓	**2019**	**2020**	**2019**	**2020**	**2019**	**2020**	**2019**	**2020**
T_1W_0	[T_1: WDSR(Broadcasting), W_0: Weedy check]	37382	39562	67764	68525	30382	28963	0.81	0.73
T_1W_1	[T_1: WDSR(Broadcasting), W_1: Pretilachlor 0.75 kg/ha as pre-emergence 0.75 kg/ha as Pre-emergence fb Bispyribac-sodium 0.025 kg/ha (20 DAS/DAT) as post-emergence]	40632	42932	72330	74653	31698	31721	0.78	0.74
T_1W_2	[T_1: WDSR(Broadcasting), W_1: Pretilachlor 0.75 kg/ha as pre-emergence 0.75 kg/ha as Pre-emergence fb manual weeding (30 DAS/DAT)]	41532	43972	69660	71927	28128	27955	0.68	0.64
T_2W_0	[T_2: WDSR(Drum seeder), W_0: Weedy check]	35862	38012	92554	96977	56692	58965	1.58	1.55
T_2W_1	[T_2: WDSR(Drum seeder), W_1: Pretilachlor 0.75 kg/ha as pre-emergence 0.75 kg/ha as Pre-emergence fb Bispyribac-sodium 0.025 kg/ha (20 DAS/DAT) as post-emergence]	39112	41382	128072	129747	88960	88365	2.27	2.14
T_2W_2	[T_2: WDSR(Drum seeder), W_1: Pretilachlor 0.75 kg/ha as pre-emergence 0.75 kg/ha as Pre-emergence fb manual weeding (30 DAS/DAT)]	40012	42422	124659	128149	84647	85727	2.12	2.02
T_3W_0	[T_3: PTR (Farmers' Practice), W_0: Weedy check]	45372	48212	94003	87660	48631	39448	1.07	0.82
T_3W_1	[T_3: PTR (Farmers' Practice), W_1: Pretilachlor 0.75 kg/ha as pre-emergence 0.75 kg/ha as Pre-emergence fb Bispyribac-sodium 0.025 kg/ha (20 DAS/DAT) as post-emergence]	48622	51582	114586	116672	65964	65090	1.36	1.26
T_3W_2	[T_3: PTR (Farmers' Practice), W_1: Pretilachlor 0.75 kg/ha as pre-emergence 0.75 kg/ha as Pre-emergence fb manual weeding (30 DAS/DAT)]	49522	52622	113154	113235	63632	60613	1.28	1.15
T_4W_0	[T_4: PTR (Mechanized Transplanting by paddy transplanter), W_0: Weedy check]	42622	44862	109623	111923	67001	67061	1.57	1.49
T_4W_1	[T_4: PTR (Mechanized Transplanting by paddy transplanter), W_1: Pretilachlor 0.75 kg/ha as pre-emergence 0.75 kg/ha as Pre-emergence fb Bispyribac-sodium 0.025 kg/ha (20 DAS/DAT) as post-emergence]	45872	48232	129846	125423	83974	77191	1.83	1.60
T_4W_2	[T_4: PTR (Mechanized Transplanting by paddy	46772	49272	134342	134412	87570	85140	1.87	1.73

transplanter), W_1: Pretilachlor 0.75 kg/ha as pre-emergence 0.75 kg/ha as Pre-emergence fb manual weeding (30 DAS/DAT)]

WDSR: Wet Direct Seeded Rice, PTR: Puddled Transplanted Rice. DAS: days after sowing, DAT: Days after transplanting, NS: Non-significant

MSP Rice: Rs 1815/q (2019), Rs 1868/q (2020), Straw: Rs 500/q, B:C = NR/GC

Table 8.Effectofestablishmentmethodandweedmanagementongrainyieldand straw yield of winter rice (2020)

Treatment ↓	2019	2020	2019	2020
Cropestablishmentmethodsofrice (T)				
T_1:WDSR(Broadcasting)	63.47	63.19	44.97	45.62
T_2:WDSR(ModifiedDrumSeederwithfurrow opener)	104.91	105.50	45.21	46.04
T_3:PTR(Farmers'Practice)	97.30	93.38	45.53	46.36
T_4:PTR (Mechanized Transplantingbypaddytransplanter)	112.41	110.30	46.08	46.50
SEm(±)	1.83	1.99	1.02	0.85
CD(P=0.05)	5.37	5.85	NS	NS
Weedmanagementofrice(W)				
W_0: Weedycheck	83.71	81.56	44.14	45.15
W_1: Pretilachlor0.75kg/haaspre-emergencefb Bispyribac-sodium0.025	100.90	99.64	45.61	46.28
W_2: Pretilachlor0.75kg/haaspre-emergencefb manualweeding(30	98.95	98.08	46.59	46.95
SEm(±)	1.58	1.73	0.88	0.73
CD(P=0.05)	4.65	5.07	NS	NS
Interaction(TxW)				
SEm(±)	3.17	3.45	1.77	1.46
CD(P=0.05)	9.29	10.13	NS	NS