Improving Resource Use Efficiency of Cereal Based Cropping Systems with Integration of Best Management with Conservation Agriculture Under Changing Agricultural Scenarios in Cauvery Delta of Tamil Nadu

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Abstract

Cropping systems in Cauvery Delta Zone of Tamil Nadu is intensive rice based with double or triple rice crops in a year. The rice system in the region is threatened by yield stagnation, scarcity of water and labour, increased costs of cultivation, and resource degradation. During 2009-2012, we evaluated four scenarios involving a range of best management practices (BMPs) with and without conservation agriculture (CA) components for improving the system productivity and economic returns of rice-based system. Four scenarios were (i) current farmers practice (S1), (ii) BMPs with conventional tillage (S2), (iii) BMPs with conservation agricultural technologies (S3), and (iv) BMPs with conservation agricultural technologies along γ א ʿ mechanical transplanting of rice in wet season (S3) had higher economic returns (25-73%). Crop diversiýcation with maize in place of dry season rice in S4 though saved in (2O þ 0-3 ʿ inaæ ") ' ƕj ---- n system productivity while conserving the natural resources.

Keywords: Best management practices; Conservation agriculture; Rice; System productivity; Resource use e ciency; Crop diversi cation

Introduction

It is estimated that the global food production must increase by about 60% between 2010 and 2050 to meet the growing demand which is likely to be higher with developing countries [1]. Rice is the most important food crop of the developing world and staple food of millions in Asia. India has the world's largest area under rice cultivation and is one of the largest producers of white rice, accounting for 20% of global rice production. India must increase its production substantially to feed one and a half billion plus population by 2050 [2]. However, the declining yield growth rates are of particular concern in double and triple crop rice mono-cropping system [3]. Average yield growth rate of rice was 2.5% per year from 1967 to 1984 but it dropped to 1.2% during 1984- 1996 [4]. e possible causes of decline in growth rates could be many but yield stagnation or yield decline resulting from poor agronomy and soil management including intensive tillage and labor intensive planting methods are believed to be key [5].

0.17-Tf(o] TJ0.073 Tw T(system and triple cropped rice-rice-rice systems [9]. Similar to Tamil)Tj-0.031 Tw T(Nadu, India, there are millions

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of the cropping season. e soil is puddled to achieve good crop establishment, weed control, and to reduce deep percolation losses [19,20]. However, soil puddling and transplanting require large amounts of water and energy, which are getting meagre and more expensive, thus reducing the pro tability and system sustainability

Soil properties	0-15 cm soil depth		16-30 cm soil depth	
	Range	Mean Ñ S.E.ª	Range	Mean Ñ S.E.ª
Clay (%)Ñi				

rice crops were transplanted in puddled soil and residue removed in S1. Other key farmer's key management practices include: transplanting of 20-30 days old seedlings at random spacing, addition of pre emergence herbicide followed by only hand weeding for weed control and thin lm of water maintained at the time of planting (Table 3). Scenario 2 included available BMPs with conventional tillage and partial residue (stubbles) incorporation in rice-black gram-rice rotation. Scenarios 3 and 4 both had BMPs with conservation tillage and residue mulch but S3 had rice-black gram-rice rotation and S4 had rice-maize-maize or rice-maize-rice rotation.

e best management practices: e BMPs used in this study were (a) improved crop cultivar/variety to t a given scenario, (b) certi ed seeds and seed treatment with Pseudomonas uorescens 10 g/kg of seeds to prevent seed borne diseases, (c) improved raised bed or mat nursery for rice to produce robust, healthy young seedlings, (d) applying adequate nutrients in a nursery to enrich seedlings with nutrients and to minimize transplanting shock, (e) optimum seedling age for rice (15-20 days both for wet and dry seasons), (f) planting two to three seedlings per hill at 22.5 × 22.5 cm spacing, (g) e cient water management by maintaining a thin lm of water at the time of planting and followed by alternate wetting and drying method of water management, (h) cono weeder operation was done at 14 and 25 DAT and hand weeding at 60 DAT both in wet and dry seasons, (i) applying adequate nutrients at the right time and following generic principles of site-speci c nutrient management (SSNM), and (j) need based pest management to control pests and diseases. A detailed account of crop

Activity/operation	Scenario 1	Scenario 2	Scenario 3	Scenario 4
(a) Wet season rice				

Weed control Pre-emergence herbicide application (0.99 a.i. l ha^{-1})	Butachlor	None	Butachlor	Atrazine	
Hand weeding (no.)	15, 30, and 60 DAT	14 and 25 DAT cono weeder operation was given. 60 DAT hand weeding was done.	If needed hand weeding according to the weed growth. Glyphosate spray was applied after the crop harvest.	40-45 DAS	
Insect and disease control Pesticide application 2009-10	Pseudomonas þuorescens @ 600 g/l and Butachlor @ 1 kg/ha and Chlorpyriphos @ 500 ml/ha	Pseudomonas þuorescens @ 600 g/l and Chlorpyriphos @ 500 ml/ha	Pseudomonas þuorescens @ 600 g/l and Butachlor @ 1 kg/ha and Chlorpyriphos @ 500 ml/ha	600 g/l and Chlorpyriphos @ 500 ml/ha	Pseudomona 600 g/l and B and Chlorpyr

as h ha^{-1}. The cost of pumping for irrigation was obtained from the Electricity Board of Tamil Nadu, which is a fixed charge per pump per horsepower. Gross returns (GR) for rice, maize, and blackgram were calculated by multiplying the grain yield of crops by the minimum support price offered by the government of India [40-42]. Net returns (NR) were calculated as the difference between gross returns and the total cost of cultivation (NR = GR -TCC). The benefit-cost ratio (BCR) was calculated as the ratio of gross returns (GR) to the total cost of cultivation (TCC) (B:C = GR/TCC). System net returns (SNR) were calculated by adding the net returns of all crops within the 12- month cycle.

Data Analysis

Data were subjected to analysis of variance (ANOVA) using the general linear model (GLM) procedures of the Statistical Analysis System (SAS Institute, 2001). The Tukey protected least significant difference test at P<0.05 level was used to test the differences between the scenario means.

Results and Discussion

Weather

The total amount of rainfall received during the study period (Oct-Sep) was 1367 mm in 2009-10, 1483 mm in 2010-11 and 827 mm in 2011-12 (Figure 1). The rainfall during wet season rice (Oct-Jan) was 893 mm, 917 mm and 586 mm in first, second and third year, respectively. Cauvery Delta Zone receives substantial rainfall during North East Monsoon which is coinciding with key growth stages of wet season rice (October- November). Dry season rice (June-Sep) received rainfall of 372 mm, 426 mm and 205 mm, respectively, in first, second and third year. The rainfall during both wet and dry seasons was not sufficient to grow rice hence the crops largely depended on irrigation from bore wells and or Mettur Dam. Summer (Feb- May) received rainfall of 101 mm, 138 mm and 35 mm in first, second and third year, respectively and hence growing of maize was feasible with supplemental irrigation. The trends of monthly mean minimum and maximum temperature were similar in all three years of experiment.

Crop residue retention

The amount of above ground crop residues retained varied greatly among the four scenarios in all three years of study (Table 4). At the start of study in the first season (wet season, 2009-10), the entire crop residues were removed hence no data are shown. But in subsequent seasons, crop residues were either removed or retained. In S1, all residues were removed at ground level at the harvest of each crop. In S2-S4, where crop residues were retained, either incorporated into the soil (S2) or applied on soil surface as mulch (S3-S4), varied significantly among the scenarios. On a system basis, the total amount of crop residues retained in three years were 13.7, 25.9 and 20.9 Mg ha^{-1} in S2, S3 and S4, respectively. Overall, the amounts of residues retained in the summer season were higher than in wet and dry seasons which were due to higher residues produced by wet season rice. The amounts of residues retained were higher in S3 than S2 in all three years while residues retained in S4 were on par with S3 in two years. This was because of 70 of machine harvested rice straw were mulched in S3 and S4 against 30 cm of rice straw from ground level were mulched in S2.

Crop and System Yield

The rice yields or rice equivalent yields of maize/legume during different seasons are presented in Table 5. The yields of wet season rice were not different in years 1 and 3 except S4 which had lower yield in year 1 and higher yield in year 2 compared to S1 (Table 5). During summer, rice equivalent yield of legume/maize were not different in years 2 and 3 except lower yield in S3 in year 3. In year 1, rice equivalent yield of legume was higher in S2 followed by S3 and S4. Though actual yields of legume were lower than those of maize, rice equivalent legume yields were higher/similar to rice equivalent maize yields [40]. These differences resulted from the differences in economic values of different crops: legumes had higher economic returns ($ 0.64/kg of blackgram in year 1 and 2 and $1.55/kg of blackgram in year 3) then those of maize $ 0.22-0.24/kg). Also, the maize suffered because of untimely rain in year 1 resulting in lower yield The legume yield in S2 was higher (by 30-69%) than S3 in two out of three years which was due to early sowing and utilization of residual moisture more effectively than S3 [41].

Scenario*	Rice (Wet Season)	Legume/Maize (summer season)	Rice/Maize (dry season)	System
		2009-10		
1	0.0	-	-	-
2	0.0	1.4 c[a]	1.6† a[a]	3.0 c[a]
3	0.0	3.6 a	1.2† b	4.9 a
4	0.0	3.0 b	0.6‡ c	3.6 b
		2010- 11		
1	-	-	-	-
2	1.8 b[a]	1.8 b	2.3† a	5.9 b
3	4.0 a	4.6 a	2.0† a	10.5 a
4	1.7 b	6.1 a	1.3‡ a	9.1 a
		2011- 12		
1	-	-	-	-
2	2.3 b	1.4 b	1.2† b	4.8 c
3	5.6 a	4.1 a	0.8† b	10.5 a
4	2.1 b	3.8 a	2.3‡ a	8.2 b
P (scenario X year)	< .0001	< .0001	< .0001	< .0001

* Refer to Tables 2 and 3 for description and details of the treatments.
[a] For each year, means within a column followed by the same letter are not different at the 0.05% level using Tukey's t-test.
† Residue retained of legume.
‡ Residue retained of maize.

Table 4: Scenario wise Residue (Mg ha^{-1}) retained during 2009-10, 2010-11, 2011-12.

e rice yield or rice equivalent yield of maize in dry season varied signi cantly among the scenarios in year 1 while it was not signi cant

energy across the years. e reason for higher speci c energy use was conventional farmer's practices in S1 and growing of maize during summer in S4. In contrast, BMP in S2 led to less use of speci c energy and BMP along with CA practices in S3 led to further reduction in use of speci c energy compared to farmers practice (S1) which was due to conventional method of land preparation and crop establishment. Higher speci c energy was recorded in farmer's practice of growing rice in Bangladesh [35]. Our results indicate that the integration of BMPs and CA practices had potential to save input energy by making conv us
conv use was

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and BCR in addition to lower economic value of maize compared to legumes.

Gross returns in dry season were significantly higher in S2 in all three years but it was similar with S1 in year 1 and those with S1 and S3 in year 3. In dry season, S4 had lower returns in years 1 and 2 mainly due to the poor performance of maize but rice in year 3 produced comparable net returns with S1 and S3. Only S2 had higher net returns (71-100%) in two out of three years compared to farmers practice (S1) in dry season. BCR followed trend similar to that of net returns in dry season. The lower yield in S4 was the reason for lower returns and yield has to be increased to harness the benefits of CA in S3 and S4. Whereas in other platforms, net returns were higher in S3 and S4 due to combined effect of increased yield and reduced costs [22,43].

At system level, gross returns in S1 were not significant with other scenarios in years 1 and 3. However, in year 2, S2 and S3 had higher gross returns by 54% and 27%, respectively, than S1. Similarly, net returns in S1 were not significant with other scenarios across the years except S2 in year 2 and 3. S2 had higher net returns by 166% in year 2 and 86% in year 3 compared to S1. However, CA practices were able to achieve the similar net returns of farmer's practices with less energy, labour and costs. Similar results from Bangladesh that integration of BMP and CA practices increased the economic returns of the rice–rice system by 1.8–3.0 times [35] and BMP practices increased economics in other rice growing areas as well [22,26,43].

Conclusion

Tamil Nadu is the 7th largest rice producing states in India. Green revolution transformed the irrigated areas into intensive rice based with double or triple rice crops in a year which contributes substantial share in state food grain production. However, rice based cropping systems are threatened by yield stagnation, scarcities of water and labour, increased costs of cultivation, soil fertility degradation, and uncertainty in availability of water through canal. Hence, integrating the best management practices (BMP) along with conservation agricultural technologies is needed for improving the system productivity and resource use efficiency of rice based system. This study investigated four scenarios involving farmer's practices, best management and conservation agricultural practices with diversified cropping patterns for three years. The key parameters tested were individual crop yields, system productivity, labour and energy use efficiency, and economics. Scenario 1 (S1), farmer's practices, was used as the baseline to compare S2-S4 comprising BMP and suitable conservation agricultural practices. On an annual system basis, best management practices produces 22-57% higher rice equivalent yield with less use of labour, energy and inputs than farmers practice. Similarly, adoption of BMP with CA reduced labour, inputs and energy with marginal increase in yield and net returns compared to farmers practice. On the other hand, introducing maize in place of rice in the diversified scenario had not increased either system yields or economic returns due to low yield of maize in dry season. This study concluded that productivity and economic returns of rice based cropping systems can be increased by adopting best management and conservation agricultural practices in Cauvery Delta Zone of Tamil Nadu. However, selection of alternative crops/management practices is crucial and thus need more medium to long-term adaptive system research to identify compatible alternative crops/management practices to diversify the food production and increase the systems productivity while conserving the natural resources.

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