Indian Journal of Agricultural Sciences **83** (3): 326–30, March 2013/Article

Economic appraisal of rice (*Oryza sativa*) based cropping sequences in major soil series of upper Asom

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Received: 5 June 2012; Revised accepted: 1 February 2013

ABSTRACT

Monocropping of rice in Brahmaputra valley of Asom region has led to deterioration of soil quality, a serious threat to its sustainability. Therefore on farm field experiments were conducted during 2005 to 2007 at four different sites, viz siteI (Nogaon), siteII (Hatichungi), siteIII (Chowkhatbharalua) and siteIV (Baruabari) in dominant soil series of Jorhat district of Assam to evaluate production potential, resource use efficiency and economics of four rice (*Oryza sativa* L.) based cropping systems (1.rice-fallow, 2. rice–potato, 3. rice –pea and 4. rice-mustard) at two levels of management, i e farmers practices (FP) and recommended package of practices (RPP). The cropping system productivity in terms of Rice Equivalent Yield (REY) of rice–potato cropping system (155.9 q/ha) in *Aeric Fluvaquents* with RPP was found economically significant followed by *Fluvaquentic Endoaquepts*(131.83 q/ha) and *in Typic Endoaquepts,* (109.6 q/ha), whereas rice–pea (102.2 q/ha) performed best and found economically viable in *Typic Fluvaquents* under flooded situation. Thus rice-potato system is productive, sustainable, resource-use efficient and remunerative cropping system followed by rice-pea and rice-mustard. Recommended package of practices performed better over farmers practice at all the sites for all cropping systems but specifically best results were recorded at Nogaon (*Aeric Fluvaquents*). Rice–potato cropping system gave highest gross returns in *Aeric Fluvaquents* (₹ 103 097 ha) followed by *Fluvaquentic Endoaquepts* (₹ 91 168 ha) and in *Typic Endoaquepts* with RPP (₹ 72 975 ha) was found economically significant, whereas rice-pea gave highest gross return ₹ 95108/ha in *Aeric Fluvaquents.*

Key words: Asom, Hydric soils, Management levels, Rice based systems, Rice equivalent yield.

Brahmaputra valley in Asom is bestowed with adequate natural resources (Land and water) essential for multiple cropping. The total net sown area is 2.77 million hectares with fallow of 1.55 million hectares. The rice (*Oryza sativa* L.) is grown in 1.743 million hectares with a production of 2.471 million tonnes (average yield of 1 439 kg/ha) (Agricultural Statistics 2010). Total area under different crops is 0.45 million hectares. Incidence and expansion of multi-nutrient deficiencies in the soils under intensive cropping in general, and in rice-based cropping systems in particular, can be linked to inadequate and unbalanced nutrient input and are considered major reasons for observed declines in productivity associated with fertilizer use (Singh *et al.* 2009). Crop diversification shows lot of promises in alleviating these problems besides, fulfilling basic needs for cereals, pulses, oilseeds and vegetables for regulating farm income. A cropping system signifies the sequence of crops grown over a specific piece of cultivated land and a period of time to increase the benefits from the available physical resources. Therefore, the basic approach in an efficient cropping system is leading to higher production and better economic returns (Yadav *et al.* 1998). Cropping system needs to be inherently flexible to take advantage of economic opportunities and or adapt to environmental realities. Inclusion of pulses, oilseeds and vegetables in the system is more beneficial than cereals after cereals, and such inclusion in a sequence changes the economics of the crop sequences. (Gangwar *et al.* 2004). Oilseeds and pulses including vegetables are receiving more attention owing to higher price due to increased demand. Inclusion of these crops in a sequence changes the economics of the cropping sequences (Tomar and Tiwari 1990).

Hence, efforts are being made to promote diversification of rice- based cropping sequence in this zone of country with legumes and vegetable crops for sustaining the productivity and meet out demand for vegetables, pulses and oilseeds.

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Therefore, the present investigation was carried out to find out most productive, resource-use-efficient and remunerative cropping system for this region.

MATERIALS AND METHODS

The on farm field experiments were conducted at four different soil sites in Jorhat district of Asom, viz village Nogaon (siteI), (26°37'21" N and 94°20'43" E, *Coarse loamy, mixed, Aeric Fluvaquents*), hatichungi (siteII), (26°40'45"N and 94°12'34"E, *Fine loamy, mixed Fluvaquentic Endoaquepts*), chowkhatbharaluwa (siteIII), (26°49'06" N and 94°22'56" E, *Fine loamy, mixed, Typic Endoaquepts*) and baruabari (siteIV), (26°49'00"N and 94°14'00"E, *Coarse silty mixed, Typic Fluvaquents*). Soil site characteristics are presented in Table1. Experimental area is the part of Brahmaputra river basin with general elevation of 80 to 120 m above MSL.

The field experiments were conducted from November 2005 to December 2007. During *kharif* two short duration rice varieties, viz Basundhara and Satyarnjan were grown under four rice-based cropping sequences under two management levels, i e farmers practices (FP) and recommended package of practices (RPP). The cropping sequences consisting of (i) Rice-fallow under FP, while (ii) Rice-potato, (iii) Rice-pea and (iv) Rice-mustard under RPP (Assam Agricultural University (AAU), Jorhat). The cropping sequences were (i) Rice-fallow, (ii) Rice-potato, (iii) Rice-pea and (iv) Rice-mustard, evaluated in spilt-split plot design (Cochran and Cox 1957) with 5 replications for their production potential and economics. The plot size was 50 m^2 each and raised under rainfed conditions. Rice seedling was prepared in nursery with 60 kg seeds for transplanting of one hectare area as per standard recommendation of DOA (1977). Seed rate for potato 25 q/ha and for pea and mustard was 40 and 15 kg/ha, respectively.

The field preparations for each crops varies. Post harvested rice fields are ploughed thrice and leveled by wooden plank for pea cultivation. Rows are prepared for sowing of pea (Azad 1) manually. The field for mustard (T 39) was prepared by ploughing 5 times followed by laddering/planking for fine tilth to facilitate the germinations of mustard. For potato (Kufri Megha), the land was ploughed thrice. Ridges and furrow were made manually at 50 cm spacing and plant to plant distance was kept at 15 cm.

Recommended doses of NPK (kg/ha) for potato 60:100:100, for pea 20:40:0 and for mustard 60:40:6 has been taken into consideration. Fertilizers N, P_2O_5 and K_2O were supplied through urea, single super phosphate (SSP) and muriate of potash (MOP) respectively. Half the quantity of recommended N and entire amount of P_2O_5 and K_2O has been applied as basal dose as per the recommendation of Assam Agricultural University. Potato, pea and mustard crops were sown in 2nd week of December. Remaining half dose of N has been applied in two splits, i e one at 45 days after sowing and 2nd as top dressing at 60 days after sowing of crops. Similar practices were also followed for rice with the application of 40:20:20 N, P_2O_5 and K_2O/ha. No fertilizer, plant protection and intercultural operations were applied in farmers practice at all the locations. Two intercultural operations have been carried out, i e one at 30th and second at 50th days after sowing for recommended package of practices at experimental sites.

Table 1 Soil–site characteristics at experimental sites

Particulars	*Coarse-loamy Aeric Fluvaquents* (siteI)	*Fine-loamy Fluvaquentic Endoaquepts* (siteII)	*Fine-loamy Typic Endoaquepts* (siteIII)	*Coarse-silty Typic Fluvaquents* (siteIV)
Slope	Very gently (1-3 %)	Nearly level (0-1%)	Nearly level (0-1%)	Nearly level (0-1%)
Elevation MSL (m)	120	100	90	80
Physiography	Lower piedmont	Gently sloping upland	Very gently sloping plain	Lower flood plain
Sand	54.0	21.03	48.22	42.70
Silt	29.5	45.13	31.28	34.90
Clay	16.5	33.84	20.50	22.40
pH (H_2O 1: 2.5)	5.5	5.2	5.1	5.0
OC (%)	1.06	0.80	1.26	1.26
CEC	6.0	10.7	12.82	5.28
Base saturation (%)	98.0	55.0	98.00	18.00
Drainage	Poor in rainy season and well drain winter	Poor in rainy season and well drain winter	Poor in rainy season and moderately well in winter	Poor in rainy season and moderately well in winter
Water table (m)	3.5	3.0	(flooding) 1.5	(flooding) 1.00
		Soil fertility status Kg/ha		
N	264.5	352.8	352.8	423.36
P_2O_5	3.23	20.27	3.67	3.09
K_2O	145.86	165.43	91.37	90.6

The periodical observations of plant height (cm), roots, branches and tillers, number of pods, plant dry weight, were recorded. At the time of harvest, number of panicles/plant and grains/panicles (rice), number of tuber/plant (potato), pods (mustard and pea) were recorded. Yield/plant in gram and one m^2 area were recorded for all crops, in 5 places in a plot and average yield has been expressed in q/ha.

The economics of each cropping sequence was computed with minimum support price or prevailing market rate of product (rice @ ₹ 650/q, potato @ ₹ 300/q, mustard @ ₹ 2 400/q, green pea pods @ ₹ 900/q, rice straw, potato haulm, mustard stover and pea fodder @ ₹ 20 q) were taken for economics. To calculate rice equivalent yield, the average yield of both rice cultivars were taken. Rice crop equivalent yield was calculated.

Y = the economic yield of 1 to n number of crops (Q/ha/year) REY = $\sum$ (yi, ei)

where REY, Rice equivalent yield (Q/ha/year), i e the rice equivalent factor and calculated as PC/PR, where PC is the price of a unit weight of *rabi* crop and PR is the price of a unit weight of rice and i = 1 to n number of crops (Lal and Ray 1976).

RESULTS AND DISCUSSION

Crop yields

Among the crops the potato crop was recorded significantly highest yield (mean of all locations) 141.9 followed by rice 55.4, pea 46.4 and mustard 5.77 q/ha. Whereas, highest rice equivalent yield (REY, mean of all locations) was recorded by the potato (65.5) followed by pea (64.3), rice (56.4) and mustard (21.31) q/ha (Table 2). The *Aeric Fluvaquents*(P1) recorded highest (REY) yield (70.43) followed by *Fluvaquentic Endoaquepts* (P2, 63.52), *Typic Endoaquepts* (P3, 42.77) and *Typic Fluvaquents* (P4, 24.47 q/ha). Recommended package of practices recorded higher yields of crops (64.68 REY) as compared to farmer practice 27.12 q/ha. Interaction of cropping system, soil site and RPP shows that highest yield of potato (208.0) was observed in *Aeric Fluvaquents* with RPP, followed by *Fluvaquentic Endoaquepts* (182.5), *Typic Endoaquepts* (125) and *Typic Fluvaquents* (52.1) q/ha. Similarly yields of rice, pea and mustard also observed same pattern. In terms of REY, highest yield of potato was recorded in *Aeric Fluvaquents* (96) with RPP followed by *Fluvaquentic Endoaquepts* (84.2 q/ha), pea (80.3 q/ha) in *Aeric Fluvaquents* and *Fluvaquentic Endoaquepts* (76.6 q/ha) and rice (60.6 q/ha) and mustard (35.0 q/ha) in *Aeric Fluvaquents*.

Table 2 Soil-site wise crop yields and rice equivalent yield

Cropping system	Nogaon	Hatich-ungi	Chowkhat bharaluwa	Barua-bari	Mean
Crop yield (q/ha)					
Rice–fallow	28.45	27.20	26.40	26.25	27.12
Rice (RPP)	60.6	54.2	53.37	54.6	55.47
Potato(RPP)	208.0	182.5	125.0	52.1	141.9
Pea (RPP)	58.0	55.3	38.7	33.4	46.4
Mustard (RPP)	9.48	8.1	4.6	0.9	5.77
Man RPP	91.83	81.97	56.1	28.8	64.68
Rice equivalent yield(q/ha) of crops					
Potato (RPP)	96.0	84.2	57.7	24.1	65.5
Pea (RPP)	80.3	76.6	53.6	46.3	64.3
Mustard (RPP)	35.0	29.9	17.0	3.32	21.32
Man RPP	70.43	63.57	42.77	24.57	50.34
Rice equivalent yield of cropping systems (q/ha)					
Rice–Fallow(FP)	28.45	27.20	26.40	26.25	27.12
Rice–Potato(RPP)	155.90	137.83	109.60	78.03	120.34
Rice–Pea(RPP)	141.71	131.80	106.80	102.20	120.60
Rice–Mustard (RPP)	95.50	83.70	69.00	57.22	76.35
Mean (RPP)	131.04	117.78	95.13	79.15	105.75
Site Mean all	105.39	95.13	77.95	65.93	86.10
CD (P=0.05)	22.17	9.97	13.58	6.61	

System productivity: The cropping system productivity in terms of Rice Equivalent Yield (REY pooled data) shows that rice–pea cropping system produced 120.60 REY(mean of all locations) as compared to rice-potato with an REY of 120.3 under RPP was found economically significant both at par followed by rice-mustard (76.35) and rice-fallow cropping system (27.12 q/ha). Similar results were also reported by Sharma *et. al.* 2004 and Singh *et. al.* 2007. Recommended package of practices performed (105.75) better over farmers practice at all the sites for all cropping systems. Among the soils sites, *Aeric Fluvaquents* observed highest yield (105.39 q/ha), *Fluvaquentic Endoaquepts* (95.13), in *Typic Endoaquepts* (77.95) and *Typic Fluvaquents* (65.93 q/ha) under RPP**.** The interaction of cropping system, soil site and package of practice, shows that the productivity in terms of REY of Rice–potato cropping system in *Aeric Fluvaquents is* 155.9, It can be attributed mainly to potato which fetched due to its higher marketable yield (208 q/ha). The next in the order was rice- pea cropping sequence at *Aeric Fluvaquents* (141.71). Hence, pea contributed most due to higher prices (₹ 900/q) in the market besides having good productivity (120.6 q/ha) to enhance the equivalent yield. Rice–potato at *Fluvaquentic Endoaquepts* (137.83q/ha) and in *Typic Endoaquepts* with RPP (109.6 q/ha) was found economically significant, whereas rice-pea performed best and found economically viable in *Typic Fluvaquents* under flooded situation (102.2 q/ha). Thus rice -potato system is productive sustainable, resource-use efficient and remunerative cropping system followed by rice-pea and rice-mustard systems. Recommended package of practices performed better over farmers practice at all the sites for all cropping systems but specifically best results were recorded at Nogaon site (*Aeric Fluvaquents).*

These results corroborates the findings of Singh *et al.* (2007) who reported rice-pea-okra followed by rice-pea-

onion as the most productive cropping sequence for eastern Uttar Pradesh, India. Sharma *et al.* (2004) and Sharma *et al.* (2007) also reported higher productivity and profitability through inclusion of vegetables and pulses in rice-based cropping system. The contribution of *rabi* crops to REY of rice-potato, rice-mustard and rice–pea was 35%, 34%, and 18%, respectively. Lowest REY (27.12 q/ha) was recorded under rice-fallow system. It clearly shows the importance of *rabi* crops to raise system productivity, sustainability and crop intensity. Among the cropping sequences involving *rabi* crop with RPP, lowest REY was recorded with rice-mustard (76.35 q/ha). Similar results were also reported by Sharma *et al.* (2004) and Singh *et al.* 2007.

Resource-use efficiency: The rice–potato (155.9) and rice–pea (141.7) cropping systems are most productive, sustainable, resource-use efficient and remunerative cropping system followed by rice-mustard systems (95.5) q/ha at *Aeric Fluvaquents* and similar results were observed at *Fluvaquentic Endoaquepts* and *Typic Endoaquepts* (Table 2). *However*, in *Typic Fluvaquents*, rice–pea cropping system is found to be most productive sustainable, resource-use efficient and remunerative cropping system followed by rice–potato and rice-mustard systems. But flooded locations have not shown any positive contribution neither for rice nor for *rabi* crops.

ECONOMIC ANALYSIS

Gross return: Rice-pea cropping system recorded highest gross returns in monetary terms (₹ 80 948) followed by rice-potato (₹ 79 886) and rice-mustard (₹ 51 081/ha/year), while the lowest (₹ 18 197/ha/year) was recorded with rice-fallow system (Table 3). Similar results were also reported by Sharma *et al.* (2004) and Singh *et al*. (2007). RPP yielded significantly highest gross returns (₹ 70 639/ha/year) as compared to farmers practice that (₹ 18 197/ha/year). Among the soil sites highest gross returns are recorded from *Aeric Fluvaquents* (₹ 70 288)**,** followed by *Fluvaquentic Endoaquepts* (₹ 63 444), *Typic Endoaquepts* (₹ 52 157)**,** *and Typic Fluvaquents* (₹ 44 226/ha/year), under RPP. The gross return of rice–Potato cropping system is ₹ 103 097/ha/year in *Aeric Fluvaquents* followed by ₹ 91 168/ha/year in *Fluvaquentic Endoaquepts* and ₹ 72 975 in *Typic Endoaquepts* was found economically significant with respect to rice-pea giving returns of ₹ 95 108/ha/year in *Aeric Fluvaquents***.** However in *Typic Fluvaquents***,** rice-pea performed better and gave gross returns of ₹ 68 566 as compared to rice-potato (₹ 52 302) and rice-mustard (₹ 38 379)/ha/year.

Table 3 Economic analysis of cropping systems in major soil groups of Jorhat district

Cropping system	Nogaon	Hatich-ungi	Chowkhat bharaluwa	Barua-bari	Mean
Gross return (₹/ ha.)					
Rice-Fallow(FP)	19 131	18 274	17 728	17 655	18 197
Rice-Potato (RPP)	103 097	91 168	72 975	52 302	79 886
Rice-Pea (RPP)	95 108	88 397	71 729	68 566	80 948
Rice-Mustard (RPP)	63 817	55 935	46 194	38 379	51 081
Mean(RPP)	87 341	78 500	63 633	53 082	70 639
Site Mean all	70 288	63 444	52 157	44 226	57 528
Cost of cultivation (₹/ha)					
Rice-Fallow(FP)	11 790	10 281	10 861	10 849	10 945
Rice-Potato (RPP)	41 466	38 323	34 158	26 093	35 010
Rice-Pea (RPP)	40 025	37 815	30 941	29 594	34 594
Rice-Mustard (RPP)	26 374	23 961	22 476	18 980	22 948
Mean(RPP)	35 955	33 366	29 192	24 889	30 851
Site Mean all	29 914	27 595	24 609	21 379	25 874
Net return (₹/ha)					
Rice-Fallow(FP)	7 341	7 993	6 867	6 806	7 252
Rice-Potato (RPP)	61 631	52 849	38 622	26 045	44 876
Rice-Pea (RPP)	55 083	50 582	40 788	38 972	45 354
Rice-Mustard (RPP)	37 443	31 975	23 718	19 399	28 133
Mean(RPP)	51 386	45 135	34 376	28 139	39 454
Site Mean all	29 364	26 564	20 622	17 473	23 354
B:C ratio					
Rice-Fallow(FP)	1.62	1.74	1.63	1.62	1.65
Rice-Potato (RPP)	2.49	2.44	2.14	2.00	2.27
Rice-Pea (RPP)	2.38	2.34	2.32	2.32	2.31
Rice-Mustard (RPP)	2.42	2.33	2.10	2.02	2.23
Mean (RPP)	2.43	2.37	2.19	2.11	2.28
Site Mean all	2.23	2.21	2.05	2.00	2.12
Cost of production (₹/q)					
Rice-Fallow(FP)	414.0	378.0	411.4	412.5	404.0
Rice-Potato (RPP)	266.0	271.2	310.8	334.4	295.6
Rice-Pea (RPP)	282.4	286.9	289.8	289.6	287.2
Rice-Mustard (RPP)	276.2	286.3	325.7	331.7	305.0
Mean (RPP)	275.0	281.5	308.8	318.6	296.0
Site Mean all	309.7	305.6	334.4	342.1	323.0

Cost of cultivation

The cost of cultivation amounts to ₹ 35 010 for rice-potato cropping system because of seed cost, high yield needs more processing cost, high cost of transport, more quantity of seed (25 q/ha) and earthing up, followed by rice-pea (₹ 34 466) and rice- mustard (₹ 22 948 ha/year), while ₹ 10 945/ha/year for rice-fallow system. RPP had higher cost of cultivation (₹ 30 851/ha/year) as compared to FP. Among the sites, the cost of cultivation varied from ₹ 29 914 in *Aeric Fluvaquents*, to ₹ 27 595 in *Fluvaquentic Endoaquepts,* ₹ 24 609 in *Typic Endoaquepts* and ₹ 21 379/ ha/year in *Typic Fluvaquents* (Table 3). The cost of

cultivation for rice-potato under RPP is ranked in the ascending order as in *Aeric Fluvaquents, Fluvaquentic Endoaquepts, Typic Endoaquepts***.** The rice-pea system is good at *Typic Fluvaquents* with a cost of cultivation of ₹ 29 594 due to high cost of seed and more production needs more labour for picking and expenditure on transport followed by rice-potato (₹ 26 093) and rice-mustard (₹ 18 980/ha/year) under RPP.

Net return: The net returns of rice-pea cropping system is ₹ 45 354, whereas for rice-potato yields returns of ₹ 44 876 and rice- mustard ₹ 28 133/ha/year . The lowest net returns of ₹ 7 252/ha/year in rice-fallow is recorded. The net returns are generally high under RPP (₹ 39 454/ha) as compared to farmers practices (₹ 7 252/ha/year). The net returns are high in *Aeric Fluvaquents* (₹ 51 386) followed by *Fluvaquentic Endoaquepts* (₹ 45 135), *Typic Endoaquepts* (₹ 34 376/ha/ year) and lowest in *Typic Fluvaquents* (₹ 28 139/ha/year) Rice-potato recorded net return of ₹ 61 631 under RPP and ₹ 52 849 under farmers practice at Nogaon site (*Aeric Fluvaquents).*The rice-pea system in *Fluvaquentic Endoaquepts* gave returns of ₹ 55 083 under RPP, over farmers' practice (₹ 50 582/ha/year) respectively, whereas at *Typic Endoaquepts* have net returns of ₹ 40 788/ha/year in rice-potato and in rice-mustard systems as against low net returns of rice fallow in *Typic Fluvaquents*.

Monetary benefit from cost of cultivation to gross returns: The seasonal benefit: cost ratio is 2.31 for rice-pea cropping system followed by rice–potato (2.27) and rice – mustard (2.23), while the ratio less than 1 (2.65) in rice-fallow system. RPP produced significantly higher output to input (benefit: cost) ratio (2.28) as compared to farmers' practices. Among the soil sites, *Aeric Fluvaquents*, have recorded the ratio of 2.23 but reduced to 2.21 in *Fluvaquentic Endoaquepts* and 2.05 in *Typic Endoaquepts,* and 2.0 in *Typic Fluvaquents.* The out input ratio is 2.49 for rice–potato in *Aeric Fluvaquents* but decreased to 2.31 in *Fluvaquentic Endoaquepts,* whereas rice–pea is recorded 2.38 in *Aeric Fluvaquents* and 2.42 for rice–mustard while 2.0 in case of *Typic Fluvaquents* (Table 3).

Cost of production

Highest cost of production was recorded under rice-fallow system (₹ 404/q) due to its low production. While the low cost of production in rice-potato system (₹ 266/q) followed by rice-mustard and rice-pea (Table 3). Recommended package of practices had lowest cost of production (₹ 296/q) as compared to farmers' practices. Among the sites, low cost of production was recorded at *Aeric Fluvaquents* (₹ 275/q), followed by *Fluvaquentic Endoaquepts* (₹ 281.5/q) and in *Typic Endoaquepts* (₹ 308.8/ q), while highest in case of *Typic Fluvaquents* (₹ 319/q). Among the interaction maximum cost of production was observed in rice-potato system (*Aeric Fluvaquents,* ₹ 414/q) *with* rice-fallow under FP (*Typic Fluvaquents,* ₹ 413/q), (*Typic Endoaquepts,* ₹ 411/q) and in *Fluvaquentic Endoaquepts* (₹ 378/q), respectively. Lowest cost of production was recorded in rice potato (₹ 266.0/q) cropping system at *Aeric Fluvaquents* under with RPP followed by *Fluvaquentic Endoaquepts* (₹ 271.2), but in *Aeric Fluvaquents* of rice-mustard (₹ 276.2) and rice-pea systems in *Fluvaquentic Endoaquepts* (₹ 286.9/q)**.**

In terms of REY, rice-potato cropping system was taken in *Aeric Fluvaquents* in lower piedmont, *Fluvaquentic Endoaquepts* on gently sloping uplands and *Typic Endoaquepts* on very gently sloping land with recommended package of practices was found best economically viable and sustainable, resource use efficient cropping system followed by rice-pea and rice-mustard. Whereas rice-pea was performed best and found economically viable in and *Typic Fluvaquents* on flooded situation with RPP, followed by rice-potato and rice-mustard.

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