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Short Communication

Weed dynamics in crop+fish farming systems in summer fallow of double cropped lowland rice fields

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Abstract

A field study was conducted in double cropped lowland rice fields during summer of 2016 to assess the crop performance and changes in weed species and weed population in different crop (amaranth, culinary melon, fodder cowpea) + fish (catla, rohu) farming systems *vis-à-vis* sole cropping. Productivity of culinary melon and amaranth was higher when integrated with fish compared to the sole crop. Culinary melon+fish system recorded the highest rice equivalent yield (REY). Among the weeds, grasses dominated followed by sedges and broad leaved weeds. Among grasses, population of *Echinochloa colona* was the highest followed by *Isachne miliacea*, *Digitaria ciliaris* and *Eragrostis tenella*. Among broad leaved weeds, *Lindernia grandiflora* ranked first followed by *Phyllanthus niruri*, *Oldenlandia umbellata* and *Cleome rutidospermum*. Among sedges, *Fimbristylis miliacea* outnumbered others. Lower weed dry matter production and higher weed control efficiency were observed when crops were integrated with fish. Culinary melon+fish system performed better in terms of weed control and productivity.

Keywords: Amaranth, Culinary melon, Farming system, Fish, Fodder cowpea, Lowland, Rice, Weed.

In Kerala, paddy fields are part of wetland ecosystems with several noteworthy ecological and economic functions. Rice-rice-fallow is identified as a major rice based cropping system in Kerala (John et al., 2014). Diversification of crops along with a livestock component in the cropping system reduces the risk besides increasing and stabilizing the farm income.

Weeds are the major impediment to rice production. A major approach to reduce the predominance of any given weed species is to increase the diversity of crops within the cropping system. Changes in the weed species and population is also influenced by crop, cropping system, variety, type of soil, tillage, method of sowing, water, nutrient and weed management methods (Koocheki et al., 2009; Murphy and Lemerle, 2006). Hence, the inclusion of crops with different growth habits and requiring change in land configuration during summer in rice based sequences can bring about changes in the weed species diversity and their population. In this context, a study was undertaken to assess the weed dynamics (changes in weed flora and population) in different crop+fish farming systems *vis-à-vis* sole cropping during summer in the lowland double cropped rice fallows.

The field study was undertaken in the double cropped lowland rice fields of Integrated Farming System Research Station, Karamana, Thiruvananthapuram during summer 2016 (February to May 2016). Rice (var. Uma) was raised in the field selected for the study during first (*Virippu*/Kharif) and second (*Mundakan*/Rabi) crop season either as sole crop or integrated simultaneously with fish as per treatments. The

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investigation on weed dynamics was restricted to the summer season alone and during this period, the maximum temperature varied between 30.31°C and 33.60°C while the minimum temperature ranged from 20.89°C to 27.39°C. The total rainfall received was 438.13 mm. The soil of the experimental site was clayey in texture, acidic in pH, low in available nitrogen, and medium in available phosphorus and potassium status.

The experiment was laid out in randomized block design with seven treatments during summer *viz.*, T_1: fallow, T_2: amaranth sole crop, T_3: culinary melon sole crop T_4: fodder cowpea sole crop, T_5: amaranth + fish, T_6: culinary melon+ fish and T_7: fodder cowpea+ fish. All the treatments were replicated thrice. The varieties of amaranth, culinary melon and fodder cowpea used were Arun, Vellayani local and Aiswarya respectively. The amaranth (*Amaranthus tricolor* L.) variety Arun, developed through mass selection from Palapoor local is high yielding, has purple colour foliage and is photo insensitive. The culinary melon (*Cucumis melo* var. *acidulus* L. Naudin) variety 'Vellayani local', a collection from Vellayani area of Thiruvananthapuram district, is of short duration (70-75 days), and produces medium cylindrical fruits which are creamy white in colour with green stripes. The fodder cowpea (*Vigna unguiculata*) variety, Aiswarya, is a single cut variety released by Kerala Agricultural University through hybridization and selection. It is tolerant to mosaic and moderately resistant to leaf spot and leaf hoppers.

The plot size was 6 m x 6 m. In the treatments where fish was integrated with crops (T_5-T_7), half of the plot was converted into a trench of size 6m x 3m x 1m. The fish species *viz.,* catla (*Catla catla*) and rohu (*Labio rohita*) were reared together (composite culture) in the trenches. In the plots where fish was reared with crop, the fish fingerlings were released in the trenches along with the planting of the first crop of rice (*Virippu*/Kharif 2015). During summer, the portion of the plot where crops were to be the planted was converted into raised broad beds alternated with deep furrows. As the water table was high, there was standing water in the trenches and in the furrows. The crops were raised on the broad beds as per the Package of Practices Recommendations for crops of Kerala (KAU, 2016). However, herbicides or other plant protection chemicals were not applied.

The harvested produce was weighed and yield expressed in kg (per 0.5 ha or 1 ha as per treatment). The yield of component crops was also expressed in terms of rice equivalent yield using the following equation (Tomar et al., 2014).

$$\text{REY} = \frac{\text{Yield of component crop/fish x market price of component crop/fish}}{\text{Market price of rice}}$$

Weed dynamics of summer season was assessed in terms of weed composition, weed population, weed dry weight and weed control efficiency. The observations on weeds were recorded at 20 and 40 DAS using a quadrat of size 1 m x 1 m, which was placed randomly in each plot. Weeds from the sampled areas were identified and grouped into grasses, broad leaf weeds and sedges. The population of weeds was recorded by counting the number of weeds coming under grasses, broad leaved weeds and sedges in the quadrat and expressed as number per sq m. Weeds present in the quadrat were pulled out along with roots, washed, dried under shade and subsequently dried in hot air oven at 70 ± 5 °C. Such dried weeds were weighed and the weight expressed in g per sq m. Weed control efficiency was computed using the following formula suggested by Mani and Gautham (1973).

$$\text{WCE} = \frac{\text{AdWC} - \text{AdWT}}{\text{AdWC}} \times 100$$

Where,

WCE: Weed control efficiency

AdWC: Population of weeds in control (fallow) plot

AdWT: Population of weeds in treated plot

The weed samples were analysed for the content of major nutrients (N, P and K) and the nutrient removal by weeds was calculated using the formula given below and expressed as kg/ ha.

$$\text{Nutrient removal} = \frac{\text{Nutrient content (\%) x Dry matter (kg /ha)}}{100}$$

The data generated were analysed using analysis of variance (ANOVA) for Randomized Block Design (Cochran and Cox, 1965). Wherever significant differences among treatments were observed, CD (critical difference) values at 5 per cent level of significance were calculated for comparison of means. The data on population of weeds were subjected to square root transformation. Significantly low and high values were not used for statistical analysis so as to obtain greater precision in comparison of the treatments.

The highest yield was from fodder cowpea grown as sole crop followed by culinary melon grown with fish and fodder cowpea with fish (Table 1). The productivity of amaranth and culinary melon was higher when grown with fish than as sole crop. The highest rice equivalent yield (REY) was also from culinary melon grown with fish followed by amaranth grown with fish. The annual fish yield varied from 852-884 kg/ ha.

The enhanced yield of the crops when integrated with fish can be attributed to the enhanced soil moisture in the root zone due to capillary movement of water from the fish trenches surrounding the raised beds on which the crops were raised. Also, the water from the trenches, rich in added nutrients from the excreta of fish coupled with remains of the feed fed to the fish, which was used for irrigating the crops as and when needed may have aided in increasing the productivity.

The composition of weeds in various treatments is presented in Table 2. Grasses dominated followed by sedges and broad leaf weeds. Among grasses, the population of *Echinochloa colona* was the highest followed by *Isachne miliacea*, *Digitaria ciliaris* and *Eragrostis tenella*. Among broad leaf weeds, *Lindernia grandiflora* ranked first followed by *Phyllanthus niruri*, *Oldenlandia umbellata* and *Cleome rutidospermum*. Among sedges, *Fimbristylis miliacea* population was the highest.

In general, population of different weeds was less in T_6 (culinary melon+fish). *Echinochloa colona* was significantly higher in T_5 (amaranth+fish), T_4 (fodder cowpea sole crop) and T_7 (fodder cowpea+fish). The population of *Isachne miliacea* was significantly higher in the fallow plot followed by amaranthus sole crop. *Digitaria ciliaris* was significantly more in amaranth+fish and fodder cowpea+fish system. *Eragrostis tenella* was significantly higher in amaranth sole crop, while it was very low in culinary melon+fish and absent in amaranth+fish and fodder cowpea+fish systems. Among broad leaf weeds, *Lindernia grandiflora* was significantly higher in fallow (9.86/m^2) followed by

Table 1. Yield and rice equivalent yield (REY) of the crops and fishes raised during summer (kg/ ha)

Treatments	Crop yield	REY of crop	Fish yield	REY of fish
T_1: Fallow	0	0	0	0
T_2: Amaranth	5796.30	5274.63	0	0
T_3: Culinary melon	10882.41	7400.03	0	0
T_4: Fodder cowpea	23703.70	7585.18	0	0
T_5: Amaranth+Fish*	8944.44	8139.44	884.33	6029.38
T_6: Culinary melon+Fish*	19387.96	13183.81	852.00	5808.93
T_7: Fodder cowpea+Fish*	11666.67	3733.33	854.00	5822.57
CD (0.05)	-	3011.286	-	-

*Yield from 0.50 ha

Sale price of commodities: Rice: Rs.22/ kg; Amaranthus: Rs.20/ kg; Culinary melon: Rs.15/ kg ; Fodder cowpea: Rs.7 /kg; Fish: Rs.150/ kg

Table 2. Effect of treatments on the composition and population of weeds during summer (number /m^2)

Treatments	T_1: F	T_2: A	T_3: C	T_4:FC	T_5: A+F	T_6: C+F	T_7: FC+F	CD (0.05)
Grasses								
Echinochloa colona	25.27 (3.38)	89.04 (9.45)	100.39 (9.93)	253.95 (15.80)	316.98 (17.78)	86.59 (9.42)	193.74 (13.91)	3.930
Digitaria ciliaris	19.51(4.25)	15.52(3.93)	15.98 (3.94)	8.42 (2.70)	46.76 (6.83)	4.88 (2.17)	25.27 (4.56)	2.325
Oryza sativa	0	17.29(3.56)	12.2 (3.59)	15.07 (3.95)	5.65 (2.44)	1.77 (1.40)	7.98 (2.84)	-
Cyanodon dactylon	0	0	0.44	0	0	0.89	0	-
Eluesine indica	0	0	0	0.44	0.44	0	0	-
Isachne miliacea	639.73	91.86	0.44	0	0	0	0	-
Panicum repens	0	0	0.89	0	0	0	0	-
Eragrostis tenella	6.99 (2.44)	49.65 (7.07)	37.24 (6.13)	14.63 (3.58)	0	2.44 (1.70)	0	2.305
Sub total	691.5	263.36	167.58	292.51	369.83	96.57	226.99	-
Broad leaved weeds								
Phyllanthus niruri	0	4.43 (2.27)	0.44 (1.17)	0.44 (1.17)	3.10 (2.02)	2.66 (1.83)	0	-
Cleome rutidospermum	0	1.33 (1.52)	0.89 (1.30)	0.44 (1.17)	1.77 (1.65)	1.55 (1.54)	0	-
Lindernia grandiflora	9.86 (3.35)	0.44 (0.92)	1.33 (1.18)	3.55 (1.99)	0	0	0	1.091
Portulaca oleracea	0	0	0	0	0.55	0	0	-
Wedelia calendulacea	0	0.44	0	0	0.44		1.99	-
Euphorbia hirta	0	0	0	0	0	0.44	3.44	-
Marsilea quadrifolia	3.55	0.44	0.89	0	0	0	0	-
Mollugo sp.	2.22	0	0	0	0	0	1.11	-
Oldenlandia umbellata	6.31	0	0	0	0	0	0	-
Salvinia molesta	3.50	0	0	0	0	0	0	-
Ludwigia perennis	2.44	0.89	0	0	0	0	0	-
Sub total	27.88	7.97	3.55	4.43	5.86	4.65	6.54	-
Sedges								
Fimbristylis miliacea	535.11*	4.66 (2.14)	5.33 (2.31)	5.33 (2.31)	5.33 (2.30)	0	3.11 (1.77)	0.344
Cyperus rotundus	8.11 (2.92)	0.44 (0.92)	0.44 (0.92)	0.66 (0.99)	1 (1.09)	0	0.89 (1.14)	0.875
Sub total	543.22	5.10	5.77	5.99	6.33	0	4	-

F: Fish; A: Amaranthus; C: Culinary melon; FC: Fodder cowpea; Figures in parentheses denote square root transformed values

sole crop of fodder cowpea, while it was totally absent in plots integrated with fish. Among sedges, *Fimbristylis miliacea* was very high in the fallow plot (543.22/m^2). Similarly, *Cyperus rotundus* population was high in the fallow plot while it was very low in all the other treatments.

The data on population of weeds are abridged in Table 3. In general, the number of grassy weeds was more compared to broad leaf weeds and sedges. Population of grassy weeds significantly varied among treatments at 20 and 40 DAS and high population was recorded in T_1 (fallow) at both the stages. At 20 DAS, among the treatments, significantly higher population was observed in amaranth+fish (373.78/m^2) was followed by fodder cowpea+fish and amaranth sole crop which were on par. The population of grasses was significantly

Table 3. Effect of treatments on weed population during summer (number /m^2)

Treatments	Grasses		Broad leaf weeds		Sedges		Total population	
	20 DAS	40 DAS	20 DAS	40 DAS	20 DAS	40 DAS	20 DAS	40 DAS
T_1: Fallow	691.55	408	28	80.89	543.11	559.56	1262.67	1048.44
T_2: Amaranth	252.89 (15.86)	228.44 (15.12)	10.78(3.26)	9.33(3.05)	5.11	17.33(4.16)	268.78(16.35)	255.11(15.97)
T_3: Culinary melon	168(12.95)	104(10.19)	4.56(2.13)	6.00(2.43)	5.89	7.78(2.76)	178.44(13.35)	117.78(10.85)
T_4: Fodder cowpea	293.33 (17.06)	112.44(10.59)	4.44(2.09)	4.43(2.08)	6.00	8.55(2.92)	303.78(17.36)	122.87(10.98)
T_5: Amaranth+Fish	373.78 (19.30)	122.89(11.08)	6.78(2.60)	7.56(2.66)	6.22	8.22(2.86)	386.78(19.64)	138.67(11.77)
T_6: Culinary melon+Fish	96.44(9.82)	51.11(7.14)	4.33(2.08)	6.00(2.43)	0	6.67(2.57)	100.78(10.03)	63.78(7.99)
T_7: Fodder cowpea+Fish	227.56 (15.07)	97.33(9.87)	6.56(2.54)	6.44(2.51)	3.78	8.11(2.84)	237.89(15.41)	111.89(10.58)
CD (0.05)	1.490	0.679	0.548	-	-	0.546	1.496	0.708

Figures in parentheses denote square root transformed values

Table 4. Effect of treatments on weed dry weight during summer, g /m^2

Treatments	Grasses		Broad leaved weeds		Sedges	
	20 DAS	40 DAS	20 DAS	40 DAS	20 DAS	40 DAS
T_1: Fallow	130.61	101.81	14.13	61.31	202.67	116.10
T_2: Amaranth	5.11	44.48	3.18	0.73	0.35	1.27
T_3: Culinary melon	4.02	35.52	2.16	0.63	0.35	0.99
T_4: Fodder cowpea	4.28	28.91	2.02	0.35	0.60	1.07
T_5: Amaranth+Fish	4.03	28.64	2.54	0.47	0.55	1.02
T_6: Culinary melon+Fish	3.41	23.16	1.26	0.37	0	0.91
T_7: Fodder cowpea+Fish	3.62	28.09	2.64	0.48	0.30	1.03
CD (0.05)	0.655	6.893	0.634	-	0.144	-

less in sole crop of culinary melon (168 m^{-2}) and the least in culinary melon+fish (96.44 /m^2). At 40 DAS, significantly high population of grasses was recorded in sole crop of amaranth (228.44/m^2) which was followed by amaranth+fish and sole crop of fodder cowpea which were on par. The population was least in culinary melon+fish (51.11/m^2). The population of broad leaf weeds differed significantly among treatments at 20 DAS only. The population was very high in fallow (28/m^2). Among the other treatments, significantly higher population of broad leaved weeds was noticed in sole crop of amaranth (10.78/m^2). Weed population were on par in sole culinary melon, culinary melon+fish, sole fodder cowpea and fodder cowpea+fish. The population of sedges varied significantly among treatments at 40 DAS only. A very high population (559.56/m^2) was observed in fallow). At 40 DAS, among the other treatments, population was significantly higher in sole amaranth (17.33 /m^2).

In general, very high weed dry weight of grasses, broad leaf and sedges was obtained at all stages in fallow. The dry matter production of grasses differed significantly among treatments at 20 and 40 DAS (Table 4). Among the treatments significantly higher dry matter was recorded in sole amaranth (5.11 g/m^2). At 40 DAS, weed dry weight was the highest in sole amaranth (44.48 /m^2), followed by sole culinary melon, sole fodder cowpea and amaranth+fish which were on par. Dry matter production of broad leaf weeds varied significantly among the treatments at 20 DAS only. Dry matter was the highest in sole amaranth and fodder cowpea+fish which were on par, and least in culinary melon+fish The treatments differed significantly in dry matter production of sedges at 20 DAS only. The dry matter of sedges was highest in sole fodder cowpea and amaranth+fish which were on par followed by sole amaranth, sole culinary melon and fodder cowpea+fish, which were on par. Weed control efficiency of grasses, broad leaf weeds and sedges differed significantly between treatments at 20 and 40 DAS (Table 5). In grasses at 20 DAS, the highest weed control efficiency was in culinary melon+fish (85.88 %) and the least in amaranth+fish. At 40 DAS, the highest weed control efficiency was in culinary melon+fish (86.99 %) and the least in sole amaranth. With respect to broad leaved weeds, weed control efficiency was significantly higher in sole culinary melon, culinary melon+fish, sole fodder cowpea, fodder

Table 5. Effect of treatments on weed control efficiency(%) during summer

Treatments	Grasses		Broad leaved weeds		Sedges	
	20 DAS	40 DAS	20 DAS	40 DAS	20 DAS	40 DAS
T_1: Fallow	-	-	-	-	-	-
T_2: Amaranth	63.38	41.78	57.17	87.61	99.04	96.88
T_3: Culinary melon	75.48	73.36	83.30	91.75	98.91	98.56
T_4: Fodder cowpea	57.92	71.77	83.36	94.52	98.88	98.43
T_5: Amaranth+Fish	45.92	68.61	75.17	90.94	98.85	98.53
T_6: Culinary melon+Fish	85.88	86.99	83.35	92.44	100	98.76
T_7: Fodder cowpea+Fish	66.91	74.881	75.44	91.17	99.31	98.53
CD (0.05)	5.752	6.766	15.048	6.419	0.437	0.578

Table 6. Nutrient removal by weeds during summer, kg /ha

Treatments	Nitrogen		Phosphorus		Potassium	
	20 DAS	40 DAS	20 DAS	40 DAS	20 DAS	40 DAS
T_1: Fallow	35.68	36.73	12.68	8.58	42.33	29.16
T_2: Amaranth	7.88	10.58	0.68	1.23	5.76	19.60
T_3: Culinary melon	3.94	8.96	0.56	1.07	4.39	13.84
T_4: Fodder cowpea	5.14	5.78	0.42	0.76	3.47	12.22
T_5: Amaranth+Fish	6.61	7.47	0.59	0.77	5.01	10.04
T_6: Culinary melon+Fish	4.28	6.32	0.50	0.59	3.06	8.35
T_7: Fodder cowpea+Fish	5.16	8.36	0.41	0.67	3.42	9.57
CD (0.05)	1.762	1.726	0.155	0.225	1.803	6.391

cowpea+fish and amaranth+fish which were on par while the least was in sole amaranth (57.17 %). At 40 DAS, all the treatments except T_2 were on par. Regarding sedges, the highest weed control efficiency was in culinary melon+fish (100 %) at 20 DAS, while at 40 DAS the highest weed control efficiency was in sole culinary melon, sole fodder cowpea, amaranth+fish, culinary melon+fish and fodder cowpea+fish all of which were on par.

Nutrient removal by weeds varied significantly among the treatments at 20 and 40 DAS (Table 6). At 20 DAS, the highest removal of nitrogen was in sole amaranth and amaranth+fish which were on par. At 40 DAS, the highest removal was in T_2 (amaranth) and T_3 (culinary melon) which were on par. Regarding phosphorus, the highest removal at 20 DAS was in amaranth, culinary melon and amaranth+fish which were on par, while at 40 DAS, amaranth and culinary melon were on par and recorded higher values. With respect to potassium, at 20 DAS, the highest removal was in amaranth, culinary melon and amaranth+fish, while at 40 DAS it was in amaranth and culinary melon.

The observed differences in the predominance of weeds between treatments may be due to variation in the growth habit of the crop, land preparation, cultural practices, microclimate, and nutrient management. For instance, the trailing nature of culinary melon may have restricted the growth of certain weeds while the dense foliage and vigorous growth of fodder cowpea may have restricted other weeds. The presence of fish and water surrounding the raised beds may have prevented the proliferation of specific weeds. The absence of any crop or land modifications provided a hospitable ambience for several weeds to flourish in the fallow plot. The higher weed population and weed dry weight in amaranth can be attributed to the large quantity of cow dung added basally @ 50 t /ha, which might have contained greater number of weed seeds. Rothuis et al. (1999) suggested that rearing of fish in fields simultaneously with rice reduced the biomass of aquatic weeds.

The study revealed that integrating of crops with fish in double cropped lowland summer fallows was a viable option which improved productivity of the crops besides generating additional income from the fish. The weed composition, population and weed control efficiency varied with the type of crop, farming system and land management.

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