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Use of botanical herbicides in system intensification

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ABSTRACT

Ten field experiments were conducted at Viswavidyalaya farm during 2004 - 14 in system intensification methodology on SRI rice (*Oryza sativa*), groundnut (*Arachis hypogea*), soybean (*Glycine max*), rapeseed (*Brassica campestris*), sesame (*Sesamum indicum*), greengram (*Vigna mungo*) and blackgram (*Vigna aureus*) crops grown in inceptisols following annual planning of weed management to find out the efficacy of botanical extracts. In all experiments varied treatments 5-12 numbers were used in RBD with 3-5 replications in plot size 3-4 x 5 m. The botanical extracts (BE) of different plants with 0.25% Tween 80 surfactants were used at 5, 10 and 100% at pre-emergence (PE) in moist soil along with two mechanical weeding (MW) at 20 and 40 DAP. Weedy check (WC), hand weeding (HW) at 20 and MW at 40 days after planting (DAP), pre-emergence (PE) herbicides at 1-2 DAP pretilachlor at 500 g/ha, alachlor at 1500 g/ha or pendimethalin at 750 g/ha + MW at 30 DAP and post-emergence (POE) herbicides quizalofop-ethyl or fenoxaprop-p-ethyl at 50 g/ha at 20 DAP + MW at 40 DAP were also used in different crops as standard check. The experiments on rapeseed and soybean during 2004-05 showed PE *Eucalyptus* leaf extract attributed 11.2% higher seed yield over WC besides two HW and pendimethalin. During 2010-11 in experiment on SRI rice, the grain yield was 6.35 t/ha in HW, 5.35 t/ha in CC, 5.16 t/ha in *Tectona* methanol extract while 3.44 t/ha in WC. In another experiment during 2010-11 on sesame, green and blackgram, the botanical extract of *Ageratum conyzoides* recorded higher growth and yield in sesame and blackgram while *Ocimum sanctum* extract among the botanicals in greengram exhibited higher harvest index, oil content and also soil nutrient status. In groundnut during 2012, average pod yield of botanical treatments was 32.5% (summer) and 42.5% (*Kharif*) which was higher than WC. Experiment on SRI rice during 2012-13 revealed that maximum WCE was obtained from HW (91%) followed by chemical control CC (84%) and BE (78%) compared to three MW (67%), two MW (53%) over WC. The mean grain yield data showed that HW recorded 88% followed by CC (79%), BE (76%), three MW (67%) and two MW (36%) over control. The maximum WCE was obtained from HW (91%) followed by CC (84%) and BE (78%) compared to 3 MW 67% and 2 MW 53%.

Key words: Botanical herbicides, System intensification, Weed management

The demand for food and processed commodities is increasing due to growing population and rising per capita income. Global food demand is expected to be doubled by 2050 while production environment and natural resources are continuously shrinking and deteriorating. Food crisis has aggravated further because of climate change and diversion of arable lands to urbanization, industrialization and also for producing bio-fuel. About 30% global emissions leading to climate change are attributed to agricultural activities, including land-use changes. Indian agriculture contributes to 8% global agricultural gross domestic product to support 18% of world population on only 9% of world's arable land and 2.3% of geographical area (Vision 2030, ICAR). There are projections that demand for food grains in India would increase to 345 mt in 2030. Hence in the next 15 years, production of food grains needs to be increased at the rate of around 5 mt annually, which is a challenge to agriculturists.

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In such situation 'System of Intensification', using integrated seed, nutrient, water, pest and quality management, is one of the possible alternatives. Biological management for eco safe soil and plant health is the basic concept of this methodology (Uphoff 1999, Ghosh 2014). The production losses due to pests are 33% and the major pest weed plant alone causes 11.5 and 12.5% global and national production losses (Ghosh *et al.* 2013). The climate change effect on biodiversity changes was observed during National Invasive Weed Surveillance (NIWS) Programme (2008-10) launched by Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India through Directorate of Weed Research, Indian Council of Agricultural Research (ICAR). More occurrence of invasive alien weed pest is posturing further threat to pest management and thereby food security (Final Report, NIWS, 2008-10). Because of easy availability and cheaper than hand weeding, the chemical weed management, has been more accepting by the farmers. Recent research under Rastriya Krishi Vikash Yajona (RKVY) Project, Government of West Bengal (Jana *et al.* 2011, Nongmaithem *et al.* 2011, Ghosh *et al.* 2012) indicated that biological management is more eco safe and less costly than chemical herbicides and would be more acceptable in system intensification (Ghosh *et. al.* 2014). The annual planning of weed management is more acceptable in system intensification because of its two basic concepts "reducing seed bank before planting and improve plant health by minimizing weed competition during critical crop weed competition".

MATERIALS AND METHODS

Ten field experiments were conducted at Viswavidyalaya Farm during 2004-2014 on SRI rice (cv.*IET 4786*), groundnut (cv.*JL 24*), soybean (*cv.Bragg*), rapeseed (cv.*B-9*), sesame (*cv.IS-5*), green (cv.*B-1*) and blackgram (cv.*WBU 108*) crops following the annual planning of weed management concept to find out the integrated efficacy of botanical extracts with mechanical weed management besides the pilot trials through UG and PG students practical classes on wasteland during 2002-2015. The following packages of annual planning of weed management were used in these experiments:

Prevention: Use of our own seeds instead of imported seeds to stop invasion of alien weeds and diversification of crops (legume crops in sequence or as intercrop or even as guard crop was used with main crop wherever possible to improve soil health).

Pre-planting care: When more than two months fallow period was available between the two main crops, cover legume crops like *Vigna* in aerobic and *Sesbania* in anaerobic were grown and incorporated at 35-50 DAS before the planting of main crop. Whenever less than one month fallow period in between two crops was available, ready mixture of nonselective 71 SG glyphosate + oxyfluorfen 23.5 EC at 2 g/litre water was used and field crops were sown at least 2-3 weeks after application of these nonselective chemicals. During land preparation *Cyperus* nuts, tubers and other weed residues were removed as far as possible.

During crop growing: At moist soil, PE ecosafe green labeled organic botanical or selective chemical herbicides followed by two mechanical weeding (weeder in anaerobic and wheel hoe in aerobic ecosystem) were used in these experiments. To avoid mixing of weed seeds with crop seeds weed plants were removed as far as possible before harvesting of crop.

The experimental soil was neutral sandy loam with moderate water holding capacity. The average annual rainfall was around 120 cm of which 80% was during June-October months. In all experiments, varied treatments (5-12 numbers) were used using RBD with 3-5 replications and in plot size of 3-4 x 5 m. The crop wise recommended fertilizer (NPK) doses were used along with 2 t/ha neem cake in each experiment. The botanical extracts (BE) of *Tectona grandis* (leaf), *Eucalyptus cameldulensis* (leaf), *Bambusa vulgaris* (root and leaf), *Calotropis procera* (young twigs), *Cucumis sativus* (matured plants) and young plants of *Parthenium hysterophorus*, *Blumea lacera*, *Ageratum conyziodes*, *Ocimum sanctum*, *Physalis minima*, *Cyperus difformis* and *Echinochloa colona* adding 0.25% Tween-80 surfactants were used at 5, 10 and 100% as pre-emergence in moist soil along with two mechanical weeding (MW) at 20 and 40 DAP. Weedy check (WC), hand weeding (HW) at 20 DAP + MW at 40 DAP, PE at 1-2 DAP chemicals (CC) pretilachlor at 500 g/ha, alachlor 1500 g/ha or pendimethalin 30 EC at 750 g/ha + MW at 30 DAP and post-emergence chemicals quizalofop-ethyl or fenoxaprop-p-ethyl at 50 g/ha at 20 DAP + MW at 40 DAP were also used in different crops as standard check. In pilot trials, 2-3 m^2 area in wasteland at Viswavidyalaya garden and farm with young weed plant seedlings were selected in each year from 2002-2015 and UG and PG students group wise sprayed the botanical extracts either as sole or in mixtures in different doses ranged from 10- 200% adding the additives. Effect of CC and BE on seed germination of crops and weeds through á amylase content along with Weed Control Efficacy (WCE), Herbicide Efficiency Index (HEI), Weed Pest Management Index (WPMI) and Net Value Production (NVP) were recorded in various experiments. The micro flora status was also tested at initial, 3 and 21 DAA and at harvest of the crops in most of the pilot and field experiments.

RESULTS AND DISCUSSION

The dominant weed species in the experimental fields were *Cynodon dactylon, Echinochloa colona, Echinochloa formosensis, Digitaria sanguinalis, Eleusine indica, Leersia hexandra, Leptochloa chinensis,Paspalum distichum, Panicum repens, Cyperus arometicus, Cyperus rotundus, Cyperus iria, Cyperus difformis* (monocots) and *Alternanthera philoxeroides, Amaranthus viridis, Chenopodium album, Melilotus alba, Melilotus indica, Digera arvensis, Physalis minima, Cleome viscosa, Stellaria media, Ludwigia octovalvis* (dicots). The pilot trials at laboratory and wasteland indicated the raw and aqueous extracts of different young weed species (*Echinochloa colona, Cyperus difformis, Parthenium hysterophorus, Calotropis procera, Amaranthus viridis, Physalis minima, Bergia capensis, Mikania micrantha, Blumea lacera, Ageratum conyziodes etc*.) and plant parts of *Tectona grandis, Cucumis sativus, Bambusa vulgaris, Ocimum sanctum, Hibiscus subdariffa etc*. when sprayed mixing with additives or surfactants at higher doses 100, 150 and 200 ml/ litre of water in moist soil as PE / POE (weeds were 1-2 leaf stages) showed maximum control of mainly the monocot species. The laboratory testing with same soil and weed seedlings against raw and aqueous extracts of botanicals showed similar inhibition effects.

During 2006-09 in three PG students SRI experiments, one treatment of botanical herbicide (raw extract of *Parthenium hysterophorus* at 50 ml/ litre of water as PE) was added to test the efficacy on rice weeds and to compare with physical (two hand weeding) and chemical (pretilachlor 50 EC at 500 g/ha as PE) weed management. Botanical treatments recorded statistically lower WCE in comparison to physical or chemical treatments.

The experiments on rapeseed and soybean during 2004-05 showed PE *Eucalyptus* leaf extract attributed 11.2% higher seed yield over WC besides two HW and pendimethalin. The amylase content of crop and major weed seeds were reduced by pendimethalin (Table 1).

During 2010-11 (Table 2) experiment on three crops namely sesame, greengram, blackgram among the nine weed management treatments namely, W_1: untreated control, W_2: hand weeding at 20 DAS, W_3: 5% (w/v) *Ageratum conyzoides* aqueous extract, W_4: 5% (w/v) *Blumea lacera* aqueous extract, W_5: 5% (w/v) *Ocimum sanctum* aqueous extract, W_6: 5% (w/ v) *Physalis minima* aqueous extract, W_7: 5% (w/v) *Amaranthus tricolor* aqueous extract, W_8: quizalofop-p-ethyl at 50 g/ha and W_9: fenoxaprop-p-ethyl at 30 g/ ha botanical treatments recorded higher crop growth and yield of sesame in the order $W_3>W_5>W_4>W_6>W_7$. In case of greengram and blackgram the order were $W_5>W_3>W_6>W_4>W_7$ and $W_3>W_5>W_6>W_7>W_4$

Table 1. Effect of pendimethalin on α-amylase activity in rapeseed and soybean crops and weed seeds germination during 2004-05

Plant species		α-amylase activity (μg maltose released per gram fresh tissue per minute)			Reduction (%) of α-amylase activity (μg maltose released per gram fresh tissue per minute) in seeds		
		Hours after treatment			Hours after treatment		
		6	24	48	6	24	48
Brassica campestris	Control	183.3	254.7	360.0	-	-	-
	Pendimethalin	173.3	227.0	313.3	5.45	10.87	12.96
Glycine max	Control	100.7	140.0	218.0	-	-	-
	Pendimethalin	96.7	129.7	184.7	3.97	7.38	15.29
Echinochloa colona	Control	186.3	232.0	361.3	-	-	-
	Pendimethalin	171.3	184.7	236.7	8.05	20.40	34.50
Eleusine indica	Control	178.0	210.0	338.0	-	-	-
	Pendimethalin	172.0	193.3	236.7	3.37	7.94	29.98
Digitaria sanguinalis	Control	140.0	154.7	271.3	-	-	-
	Pendimethalin	124.7	134.0	193.3	10.95	13.36	28.75
Cyperus rotundus	Control	212.7	268.0	413.3	-	-	-
	Pendimethalin	206.0	249.3	363.3	3.14	6.97	12.10
Cleome viscosa	Control	140.0	153.3	256.7	-	-	-
	Pendimethalin	124.7	128.7	216.7	10.95	16.08	15.58
Chenopodium album	Control	163.3	188.0	322.0	-	-	-
	Pendimethalin	148.7	154.7	238.0	8.98	17.73	26.09
Melilotus alba	Control	126.7	150.0	241.3	-	-	-
	Pendimethalin	104.0	121.3	190.0	17.90	19.11	21.27
Alternanthera philoxeroides	Control	145.3	172.7	282.0	-	-	-
	Pendimethalin	134.0	146.0	222.0	7.80	15.45	21.28
Physalis minima	Control	104.7	114.7	162.0	-	-	-
	Pendimethalin	100.7	102.0	116.0	3.82	11.05	28.40
Amaranthus viridis	Control	143.3	176.7	304.7	-	-	-
	Pendimethalin	134.7	147.3	244.7	6.04	16.61	19.69

respectively. *Ageratum conyzoides* extract recorded higher growth and yield in sesame and blackgram while *Ocimum sanctum* extract in greengram exhibited higher harvest index, oil content and also nutrient status among the botanicals. Hand weeding and eco safe chemicals though showed better WCE but considering NVP the eco safe botanicals may be considered as a substitute of traditional weed management practices. All the weed management treatments did not show any phyto-toxic effect on the crops at any date of observation. The botanical treatments recorded slightly lower soil microflora population at 7 DAS in respect to initial, which might be due to the detrimental effect of allelochemicals present in the botanical extracts that suppressed the growth of the micro flora. However, the population increased thereafter and at harvest, the botanical *Ageratum conyzoides* extract showed highest value among the botanicals.

During 2010-11 (Table 3) in experiment on SRI rice, the pooled grain yield data showed 6.35 t/ha (HW), 5.35 t/ha (CC), 5.16 t/ha (*Tectona* methanol extract) while WC recorded 3.44 t/ha. The grain yield of rice was increased 3.6% in the final year over the starting year due to annual planning of weed management. The NVP data showed that the *Tectona* methyl extract (1.39), aqueous extracts of sole *Calotropis* (1.45) and *Parthenium* (1.46) or their mixing as raw extracts (1.45) recorded lesser differences than that of hand weeding (1.59) or eco safe chemical pretilachlor 50 EC (1.67).

Results of experiment on groundnut during 2012 showed that 30 DAS HW recorded the minimum weed biomass and density because at 15 DAS, HW was done and therefore the crop faced lesser competition from weed flora in its critical crop weed competition period and thus the WCE was 100% higher than weedy check, 20.27% higher than CC

Table 2. Effect of weed management treatments on weed control efficiency (WCE) and seed yield of summer three pulse and oilseeds crops during 2010-11 (pooled data 2010 and 2011)

Treatment	WCE at 30 DAS			Seed yield in t/ha		
	Sesame	Greengram	Blackgram	Sesame	Greengram	Blackgram
W_1 Untreated control	-	-	-	0.61	0.93	1.12
W_2 Hand weeding	73.2	66.2	69.7	0.91	1.36	1.67
W_3 *Ageratum conyzoides*	32.8	32.4	32.6	0.77	1.15	1.37
W_4 *Blumea lacera*	23.8	22.7	23.3	0.71	1.05	1.19
W_5 *Ocimum sanctum*	28.8	28.5	28.7	0.73	1.20	1.34
W_6 *Physalis minima*	14.2	16.1	15.1	0.69	1.10	1.28
W_7 *Amaranthus tricolor*	7.3	11.6	9.4	0.66	0.99	1.22
W_8 Quizalofop-p-ethyl	52.5	51.8	52.1	0.83	1.30	1.48
W_9 Fenoxaprop-p-ethyl	58.7	57.0	57.9	0.85	1.33	1.49
Mean	-	-		0.75	1.16	1.35
				C	W	C×W
LSD (P=0.05)				0.031	0.044	0.077

Table 3. Impact of APWM on weed control efficiency (WCE), grain yield and NVP of summer SRI during 2012 and 2013

Treatment	WCE (%) at 25 DAT			Grain yield in t/ha				
	2010	2011	Pooled	2010	2011	Pooled	Percent increase	NVP
T_1 - Unweeded check	-	-	-	3.38	3.51	3.44	3.85	0.81
T_2 - Hand weeding	100.0	100.0	100.0	6.21	6.49	6.35	4.51	1.59
T_3 - *Parthenium* AE	24.7	28.5	26.6	4.68	4.85	4.77	3.63	1.46
T_4 - *Calotropis* AE	21.9	25.7	23.8	4.64	4.82	4.73	3.88	1.45
T_5 - *Tectona* AE	30.2	33.4	31.8	4.86	5.04	4.95	3.70	1.56
T_6 - *Parthenium* ME	27.0	30.4	28.7	4.84	5.02	4.93	3.72	1.28
T_7 - *Calotropis* ME	24.8	28.3	26.5	4.72	4.88	4.80	1.69	1.23
T_8 - *Tectona* ME	40.7	43.0	41.8	5.07	5.26	5.16	3.75	1.39
T_9 - *Parthenium* RLE	12.7	17.6	15.2	4.48	4.64	4.56	3.57	1.37
T_{10} - *Calotropis* RLE	11.7	15.7	14.1	4.40	4.55	4.48	3.41	1.32
T_{11} - *Parthenium* + *Calotropis* RLE	23.9	25.8	25.7	4.70	4.87	4.78	3.62	1.45
T_{12} - Pretilachlor 50 EC	66.5	67.5	67.0	5.25	5.45	5.35	3.81	1.67
LSD (P=0.05)				0.252	0.264	0.258		

AE- aquaous extract, ME – methanol extract, RLE- raw leaf extract, DAA- days after application and 86.59, 88.35, 75.95, 90.98, 80.16 and 76.94%, higher than the botanical treatments T_1, T_2, T_3, T_4, T_5 and T_6, respectively during the Pre-*Kharif* season. The corresponding figures for *Kharif* season were 100, 12.31, 87.41, 89.54, 75.67, 90.34, 77.37 and 76.32%. Chen. (2009) showed similar observations.

The average pod yield of botanical treatments was 32.5 (summer) and 42.5% (*Kharif*), more than WC (Table 4). during summer and *Kharif* season, the mean pod yield of botanical treatments T_3, T_6 and T_5 showed 37 and 47% while T_1, T_2 and T_4 was 28 and 38% more, respectively over the weedy check. Kernel yield data also showed similar variation among the treatments.

Experiment on SRI rice during 2012-13 (Table 5) revealed that maximum pooled WCE at 45 DAT was obtained from HW (90.5%) followed by CC (83.5%) and BE (83%) in comparison to 3 MW (66.5%), 2 MW (52.5%) over WC. The mean grain yield data in HW (88%) followed by CC (79%), BE (76%), 3 MW (67%) and 2 MW (36%) over WC treatment. The pooled WPMI values were 20.0, 11.0 and 7.5 for HW, CC and BE, respectively. The herbicide efficiency index pooled data showed CC 480 while botanical 230. The herbicide treatment BE recorded higher NPV (1.59) followed by HW (1.54) and CC (1.53) corresponding to 3 MW (1.34) and 2 MW (1.03) over WC (0.73). Chemical herbicide pretilachlor reduced the amylase content (µg maltose/ g released fresh tissue/minute) of rice more than that of the botanicals (Table 6) but in case of the dominant three weed seeds *Echinochloa colona*, *Cyperus difformis* and *Ludwigia octovalvis*, the germination inhibition was almost same by both CC and BE. Asthini (2008) also recorded similar observation.

In SRI experiment during 2012-14, the results (Table 7 and Fig. 1) revealed that in comparison to WC, the HW, CC and BE followed by 2 MW yielded 27.97, 29.39 and 23.67% more, respectively. The average yield increase in 2014 than 2012 was 13.5%. The botanicals showed inhibition effect mostly on grass weed only.

Table 4. Effect of treatments on WCE, pod yield, kernel yield and weed index of groundnut in 2012

Treatment	WCE (%)		Pod yield (t/ha)		Kernel yield (t/ha)		Weed index		% increase of pod yield over control	
	Pre-*Kharif*	*Kharif*	Pre-*Kharif*	*Kharif*	Pre-*Kharif*	*Kharif*	Pre-*Kharif*	*Kharif*	Pre-*Kharif*	*Kharif*
T_1	12.1	10.8	1.44	1.33	0.99	0.84	24.2	18.9	32.1	44.6
T_2	10.5	9.0	1.38	1.24	0.87	0.78	27.4	24.4	26.6	34.8
T_3	21.8	20.9	1.53	1.36	1.09	0.93	19.5	17.1	40.4	47.8
T_4	8.2	8.30	1.35	1.23	0.88	0.75	28.9	25.0	23.8	33.7
T_5	17.9	19.4	1.47	1.34	1.01	0.89	22.6	18.3	34.9	45.6
T_6	20.9	20.3	1.48	1.36	1.02	0.87	22.1	17.1	35.8	47.8
T_7	72.1	75.4	1.78	1.55	1.29	1.06	6.3	5.5	63.3	68.5
T_8	90.5	85.9	1.90	1.64	1.39	1.13	-	-	74.3	78.3
T_9	-	-	1.09	0.92	0.65	0.48	42.6	43.9	-	-
LSD (P=0.05)			0.39	0.25	0.36	0.27				

T_1 - 5% aqueous extract *Echinochloa colonum* ; T_2 -5% aqueous extract *Cyperus difformis*; T_3 -5% aqueous extract *Ageratum conyzoides* ; T_4 - 5% aqueous extract *Blumea lacera*; T_5 - 5% aqueous extract *Cucumis sativus* ; T_6 - 5% aqueous extract *Bambusa vulgaris*; T_7 – CC (alachlor 50 EC at 1.5 kg/ha); T_8- Hand weeding (HW) at 15 DAS and T_9- Weedy check (WC)

Table 5. Impact of APWM on WEC, herbicide efficiency index (HEI) and weed pest management index (WPMI) during summer SRI 2012 and 2013

Treatment	WCE (%) at 45 DAT		HEI		WPMI		Grain yield (t/ha)		Percent increase	NVP
	2012	2013	2012	2013	2012	2013	2012	2013		
T_1 - Weedy check	-	-	-	-	-	-	3.10	3.12	0.65	0.73
T_2 - Two MW	54	51	-	-	1	3	4.20	4.27	1.67	1.03
T_3 - Three MW	64	69	-	-	5	6	5.10	5.30	3.92	1.34
T_4- One HW + Two MW	92	89	-	-	23	17	5.80	5.93	2.24	1.54
T_5- CC + two MW	84	83	474	486	11	11	5.45	5.70	4.59	1.53
T_6- BE + two MW	77	89	200	260	7	8	5.33	5.63	5.63	1.59
LSD (0.05)							0.25	0.65	Mean- 3.12	Mean 1.29

MW- Mechanical weeding (rice weeder), HW-Hand weeding, PE- Pre-emergence CC- Chemical control; BE- Botanical control with mixture of *Parthenium*, *Calotropis* and *Tectona* aqueous extracts

Table 6. Effect of chemical and botanical weed management treatments on the amylase content in seed germination of rice and three dominant weed flora during 2013

Treatment	Amylase content (µg maltose /g released fresh tissue /minute)											
	Control				Botanical mixture				Pretilachlor			
Observations at 4 days after seed germination	24 hour	48 hour	72 hour	96 hour	24 hour	48 hour	72 hour	96 hour	24 hour	48 hour	72 hour	96 hour
Rice	185	225	210	145	153	176	151	143	119	199	83	71
Echinochloa colonum (G)	23	68	25	23	8	17	11	11	4	8	5	4
Cyperus difformis (sedge)	28	31	59	33	13	22	40	20	5	17	31	11
Ludwigia octovalvis (BL)	25	33	108	40	13	20	37	20	8	13	20	11
	Seed	TRT	S x T	S x T x H								
LSD (P=0.05)	0.64	0.56	1.11	2.23								

Table 7. Impact of annual planning and management (APWM) on the grain yield increase of summer SRI rice during 2012-14

Treatment	Grain yield (t/ha)		
	2012	2013	2014
T_1 - Weedy check	3.10	3.95	4.00
T_2 - Two MW	4.31	5.12	5.17
T_3 - Three MW	5.11	5.72	5.95
T_4- One HW + Two MW	5.82	6.49	7.00
T_5- CC + two MW	6.31	6.27	6.88
T_6- BC + two MW	6.00	6.16	6.46
Average	5.11	5.62	5.91

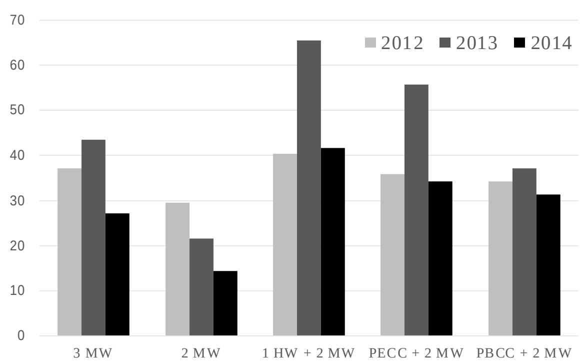

Fig. 1. Effect of annual planning and management (APWM) on% reduction of weed biomass at 45 DAT on SRI rice (2012-13-14)

The SRI experiment conducted at 11 on farm locations of different 9 rice growing districts of West Bengal to test the advantages of annual planning and management (APWM) with a package of practice of the best treatments at on station (SRI) and farmers own practice (TTR) revealed increased average productivity of rice in different locations by 5.6–19.4% in SRI than that of TTR. The results of population of soil microflora status (Table 8) indicated that there an increasing trend of total actinomycetes, fungi and bacteria population at the final year 2014 than that of the initial year 2012. The population of soil total actinomycetes at initial was minimum 94 CFU x 10^5/g soil at Gosaba , South 24 Paraganas while maximum 130 CFU x 10^5/g soil at Raina Burdwan. The corresponding figures at harvest of final year 2014 were 135 (Bangaon North 24 Parganas) and 188 (BCKV, Nadia). Similar results were also observed against total fungi [minimum 08 CFU x 10^4/g soil at Fulkalmi, Nadia and maximum at BCKV 13 CFU x 10^4/g soil at the initial year 2012 and corresponding values at final year 2014 were 23 CFU x 10^4/g soil (Bangaon, North 24 Parganas) and 33 CFU x 10^5/g soil (BCKV, Nadia)] and total bacteria [minimum 80 CFU x 10^6/g soil at Chandamari, Nadia and maximum 98 CFU x 10^6/g soil at Bhobla Paschim Medinipur at the initial year 2012 and the corresponding values at final year 2014 were 108 CFU x 10^6/g soil (Bangaon, North 24 Parganas) and 127 CFU x 10^6/g soil (BCKV, Nadia)]. The lower varied population in some location was mainly due to not continuation of SRI in same land like BCKV (Ghosh *et al.* 2014 A).

The higher yield in botanicals was mainly due to managing weed flora with the help of natural allelochemicals (*Parthenium*- sesquiterpene lactones and phenol; *Calotropis*- calotropin and mudarine; *Ageratum* -coumarin*; Cucumis* -sisymbrifolin*; Bambusa* -rutin and Tricin *; Echinochloa*- apigenin*; Cyperus*- cyperene and cyperotudone*; Physalis*- imperatorin withanoilides; *Ocimum*- essential oil ; *Blumea* -fenchane, ä- fenchone, monoterpene citral a).

When botanicals extracts are applied in sufficient moist condition a hydrogen ion can break away from the (– OH) group and transfer to a base- the position of equilibrium lies well to the left. Thus losing a hydrogen ion (because the phenoxide ion formed) phenol is stabilized to some extent. The negative charge on the oxygen atom is delocalised around the ring. The more stable the ion is the more likely it is to form. One of the lone pairs on the oxygen atom overlaps with the delocalised electrons on the benzene ring. Therefore, botanical extracts needs

Table 8. Microflora population at different on station and on farm locations in summer SRI 2012 and 2014

Locations	Actinomycetes (CFU x 10^5/g soil)				Fungi (CFU x 10^4/g soil)				Bacteria (CFU x 10^6/g soil)			
	2012		2014		2012		2014		2012		2014	
	Initial	Harvest	Initial	Harvest	Initial	Harvest	Initial	Harvest	Initial	Harvest	Initial	Harvest
BCKV	115	137	143	188	13	17	28	33	87	102	118	127
Shekhampur, Birbhum	*	*	126	143	*	*	23	26	*	*	105	111
Sriniketan, Birbhum	*	*	114	151	*	*	21	28	*	*	102	112
Fulkalmi, Nadia	119	123	147	156	08	14	19	25	85	97	112	120
Chandamari, Nadia	121	129	*	*	10	15	*	*	80	94	*	*
Raina, Burdwan	130	132	154	159	12	15	21	30	94	105	109	118
Gurap, Hooghly	114	135	152	158	12	14	22	28	96	103	112	116
Khanru, Purba Medinipur	*	*	160	167	*	*	25	29	95	101	104	112
Bhobla, Paschim Medinipur	*	*	153	168	*	*	26	31	98	112	116	124
Bangaon, North 24 Parganas	*	*	127	135	*	*	18	23	89	95	102	108
Sankrail, Uluberia, Howrah	119	126	141	157	12	17	23	27	85	97	108	116
Gosaba, South 24 Parganas	94	121	139	161	10	14	24	29	91	101	109	112

*Not done in this year

sufficient moist soil and probably for this reason, these extracts may be more active in rice field when applied at earliest after preparation. However, for confirmation of these results it needs detail studies along with proper formulation and dose of the botanical herbicides (Ghosh *et al.* 2014, Jana *et al.* 2011 and Nongmaithem *et al.* 2011)

In most of the experiments, higher NVP was observed in BE over CC and HW. An initial detrimental effect for two weeks on the soil microflora status was observed in all chemicals including botanicals though in botanicals the population of microflora reduction percentage was lower than that of the chemical synthetic herbicides. Similar results were also obtained by Chen (2009), Ghosh *et al.* (2012), Vaughan and Lehnen (1991) *etc.*

From these experiments, it could be concluded that following the annual planning of weed management (APWM), botanical herbicides integrated with mechanical weeding (more eco-safe and less costlier), are the best alternate option for weed management in system intensification. Annual planning of weed management was also able to increase our productivity by gradual reducing pest losses and increasing soil health status as it is a part of biological management in system intensification. The botanical herbicides are more safer to soil health in comparison to synthetic chemical herbicides. Mixture of botanical extracts with other botanicals or chemical herbicides need to be studied for further exploitation of these natural plant allelochemicals in various ecosystem.

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