Journal of Crop and Weed, 12(3):168-174(2016)

Bash of botanical herbicides in annual planning of weed pest management for eco-efficient sustainable agriculture

R.K.GHOSH, A. KUMAR, A. GHOSH, D. MONDAL, C. KARMAKAR, BHARATH G.N., P. BANDOPADHYAY AND G. SOUNDA

Department of Agronomy, Faculty of Agriculture,
Bidhan Chandra Krishi Viswavidyalaya, Mohanpur – 741252,
Nadia, West Bengal

Received :15.12.2016 ; Revised : 28.12.2016 ; Accepted : 30.12.2016

ABSTRACT

For global eco-safe and sustainable food, nutritional, health and ecological security against increasing population, declining of land per capita along with escalating adverse impacts of climate change, the best management practice of available resources with more biological management is best appropriate methodology in various ecosystems. National production losses due to pests are almost around one third and out of this, the major pest weed plant alone causes around 12 % production losses. Annual planning of weed pest management (APWPM) aims to reduce the weed seed bank in crop field prior to crop planting and by reducing the weed competition in critical crop weed competition period (CCWCP) improving both soil & plant health and in the long run the productivity. Based on a sequence of field and pilot experiments were conducted during last one decade on weed seed bank status and ecosafe management of weed pest the present field experiments were conducted during 2014 – 2016 to find out the weed seed bank status in various weed management practices on rice- rapeseed- okra (aerobic) crop sequence under conventional, reduced and no till system and efficacy of bio and synthetic herbicides mixture following APWPM in SI paddy at inceptisol of India to increase the productivity. The highest density of weed seeds was found in zero tillage plots under weedy check and the lowest with zero tillage also under the eco-safe chemical control management. Among the three different tillage treatments, increase in weed seed density at the end of the crop sequence was highest in zero tillage over initial (14.85%) followed by reduced tillage (13.53%) in comparison to conventional tillage (10.99%). Among the weed management practices, eco-safe chemical control showed maximum diminution in weed seeds over weedy check (58.38%) reduction over initial) at the end of a year, which was followed by botanical control (24.07%) reduction over initial). Whereas the corresponding figures for physical control (hand weeding) was a slight increasing trend in weed seeds density (3.43%) in comparison to weedy check plots (an increase of 58.24 per cent over initial). The probable reason for higher weed seed density in zero and reduced tilled plots under weedy check situation may be due to lesser soil disturbance and other micro-environmental changes created by no tillage and crop rotations probably changes selection pressures via change in management. In both experiments of summer SI paddy twice HW recorded 69.50 -70.32 per cent WCE along with the maximum mean yield of 5.01 t ha^{-1}. The treatments of mixture of natural botanicals and synthetic chemical showed better weed management (WCE 51.07- 60.91%) over the mixture of only botanicals (WCE 40.57 - 49.83%) or sole application of botanicals or synthetic chemicals (WCE 26.25-49.88%). The mean grain yield data of two experiments showed similar trends, the mixture between natural botanicals and synthetic chemical recorded 7.56, 6.55, 18.69 and 46.79 per cent more yield over the mixture of only botanicals, sole application of chemical, sole application of botanicals and weedy check, respectively The reason of lowering the weed competition in paddy crop during its' critical crop weed competition period (CCWCP) and increasing the productivity of SI paddy by using APWM may be due to reduction of weed seed bank before the rice planting and further using mixture of natural botanicals and synthetic chemicals at PE may be due to their synergistic effect further inhibition of the germinated weeds that able to create an identical apposite eco safe environment favorable for snowballing both the soil and the paddy crop health. In pilot trials of potato and mustard at 20 DAP / DAS the mixture of natural botanicals and synthetic chemicals also showed better WCE in comparison to their sole application.

Keywords : Annual planning of weed management, ready mix botanical + chemical herbicides, system intensification, weed seed bank

For eco-safe sustainable food production with considerations of nutritional, health and ecological security of more than 9 billion people (around 1.50 billion in India) by 2050 is the best management practice of available resources (perk up plant and soil health with farmers' improve thinking) in various ecosystem to combat per capita land availability along with scenarios of climate change. The biological management is the major concept in system intensification (Uphoff, 1999; Ghosh *et al*., 2014). National production losses due to pests (weed, insect, pathogens and other pests) are 33 per cent and out of this, the major pest weed plant alone causes 11.5 and 12.5 per cent world and national production losses, respectively (DWSR, 2010). Annual planning of weed pest management (APWPM) aims to reduce the weed seed bank in crop field prior to crop planting and by reducing the weed competition in critical crop weed competition period (CCWCP) improving both soil and plant health. Field and pilot experiments conducted

Email:drajr1956@gmail.com

during last one decade at inceptisol revealed that number of weed seeds in the anaerobic ecosystem were 477 per cent lesser in upper surface in comparison to under surface upto 0-15 cm depth. The corresponding figures for aerobic and roadside areas were 308 and 390 per cent. A gradual decrease in the population of weed seeds was also observed in 0-5, 5-10 and 10-15 cm soil depth. Further eco-safe and eco-efficient organic botanical herbicides in APWPM as pre-emergence either as sole or in combination with eco-safe chemical herbicides is less costly to the farmer and create an eco-sustainable environment with improved yield (Ghosh *et al*, 2015). With this contemplation, field experiments have been undertaken using system intensification to evaluate the impact of weed seed bank in invading weed flora in CCWCP and increasing crop productivity by managing weeds through APWPM giving priority on ecosafe organic chemicals including botanicals with the field crops in Gangetic alluvium. The major objectives were to find out the percent diminution of weed pest infestation and concomitant improved productivity in rice based crop sequence based on augmentation of both soil and plant health by adopting APWPM.

MATERIALS AND METHODS

Based on a sequence of field and pilot experiments conducted during last one decade on weed seed bank status and eco-safe management of weed pest, the present three field experiments were conducted at Jaguli, Instructional Farm of this Viswavidyalaya, Mohanpur during 2014-16 to find out the weed seed bank status in aerobic crop sequence under three various tillage system (experiment one) and also to find out the efficacy of botanical and synthetic herbicides mixture in APWPM in two experiments on paddy crop grown with system intensification in inceptisol of India. The experimental soil was neutral sandy loam with moderate water holding capacity with pH around neutral. The average annual rainfall is around 120 cm of which 80% is during June-October months.

In experiment 1, the field trail was conducted to find out the weed seed bank status in rapeseed (*Brassica campestris* var. yellow sarson) – Okra (*Abelomoschus esculentus*) – direct seeded rice (*Oryza sativa*) crop sequence under three tillage systems in main plots (conventional, reduced and zero tillage) and four weed management as sub-plot treatments (PE chemical herbicide at 1 DAS + mechanical weeding at 20 DAS; PE botanical herbicide at 1 DAS + mechanical weeding at 20 DAS; hand weeding at 15 DAS + mechanical weeding at 30 DAS and weedy check). The experiment was conducted following split plot design with three replications. The crops were sown in July first week (DS rice cv IET 4786) – October last week (Rapeseed cv B-9) – February first week (Okra cv NS 531). The recommended balance nutrient (N: P: K:Neem Cake:: 80: 40: 40: 2000 kg ha^{-1}); judicious water by applying irrigation only in the crop critical physiological stages and recommended ecosafe insect and disease pest management were used in this experiment. For the study of weed seed bank, twenty sub-samples were taken from individual plot size of 5 x 3 m (net plot size for weed seed bank study 7.60 m^2) from three different soil depths (0-5, 5-10 and 10-15 cm).The first sub-sample was taken at random at any site of the plot and other sub-samples were obtained by walking in zig-zag fashion from the first sub-sample site. These twenty sub-samples of one plot were composited and mixed as one sample per treatment for each treatment. The analysis of well mixed soil of 100 g was done for an adequate representation of the entire soil core (Forcella *et al*., 2011).Weed seeds were extracted and enumerated by the method described by Rahman *et al*., 1995. The individual samples were washed through a fine mesh to remove soil particles. The remainder was air dried and then passed through a descending series of sieves. Whole seeds from each sieving were extracted by hand using the projector (Document Camera), identified and counted. The seed viability test was determined by crushing the seed and inspecting the endosperm; and only those seeds exhibiting white healthy endosperm were included in the counts. The number of weed seeds in soil were counted before sowing and after harvesting of the crop as per the FAO protocol (Forcella *et al*., 2011) and converted into number m^{-2} by multiplying it with factor 68 as given by Rahman *et al*., 1997.

The two field experiments on summer transplanted rice following system intensification methodology were conducted in randomized block design having 8 and 11 treatments on rice (*Oryza sativa* cv. IET-4786) in summer SI rice–soybean (*Glycine max*) crop sequence with three replications in the plot size of 15 and 20 m^2. The treated seeds were sown at first week of February and 20 days old seedlings were transplanted using a spacing of 20 x 25 cm. The balance nutrition (N : P : K : Neem cake: 80 : 40 : 40 : 5000 kg ha^{-1}) was used along with applying irrigation 2-3 cm water at active tillering, panicle initiation and flowering and the rest time on the basis of alternate wetting and drying (AWD) principle in both the experiments. The package of annual planning of weed management (APWM) was as pre-planting care the ready mixture of non-selective Glyphosate 71 SG + Oxyfluorfen 23.5 EC @ 2 g lit^{-1} water was used a week before primary land preparation and during final land preparation *Cyperus* nuts and weed stubbles were removed as far as possible. The rice crop was grown using the BCKV farm pure rice seeds with proper seed treatment to avoid invasion of alien weeds. The PE organic botanicals aqueous extracts of *Bambusa vulgaris* (bamboo) and *Tectona grandis* (teak) in one experiment and raw extracts of *Melilotus alba* (senji methi) and *Parthenium hysterophorus* (gajar ghash) in another experiment were used either sole or in mixture with selective eco-safe green labelled chemical herbicide Pretilachlor 50 EC @ 500 g ha^{-1} was done at 1 DAT which were followed by a mechanical weeding at 30 DAT. The treatments hand weeding (HW) and weedy check (WC) were also used as standard treatments. In addition of these two experiments, three more pilot trials on weed management in reduced tillage system on potato (*Solanum tuberosum* cv Himalini) and mustard (*Brassica juncea* cv RW 351) crop grown with SI methodology were also initiated during rabi season of 2016 to find out the efficacy of i) mixture of paraquat dichloride 24 SL @ 2.5 kgha^{-1} + *Bambusa vulgaris* aqueous extracts @ 100 ml lit^{-1} water in potato; ii) mixture of paraquat dichloride 24 SL @ 2.5 kg ha^{-1} + *Cucumis sativa* (cucumber) aqueous extracts @ 100 ml lit^{-1}water in mustard and iii) only *Camelia sinensis* (tea) raw leaf extracts @ 200 ml lit^{-1} water were applied at PE in mustard crop. In all experiments for botanical treatments the nonionic surfactant was used @ 1 lit ha^{-1} and sole or mixture of chemical + botanicals were applied within a day after preparation under moist soil condition. The weed density and weed dry biomass were recorded at 20 DAP/DAS.

RESULTS AND DISCUSSION

The results that obtained in experiment 1 revealed that the size of the seed bank differed among tillage and weed management treatments (Table 1 and Fig. 1). The highest weed seeds were found in the weedy check when they were measured in zero tillage plots. While the lowest weed seed density was found also with zero tillage when the eco-safe chemical control method was applied. Among the three different tillage treatments, increase in weed seed density at the end of the crop sequence was highest in zero tillage over initial (14.85%) followed by reduced tillage (13.53%) in comparison to conventional tillage (10.99%). The fact that weed seed diversity as well as the number of viable, germinated and dormant seeds significantly increased with zero and reduced tillage and a three species crop rotation was supported by earlier predictions found in other experiments (Cardina *et al*., 2002; Sosnoskie *et al*., 2006 and Caroca *et al*., 2011). Similarly, Murphy *et al*. (2006) found 8000 seeds m^{-3} under zero tillage while 49000 seeds m^{-3} under conventional tillage after 6 years of the tillage treatments in Ontario and working on weed seed bank on effects of cropping sequence and weed management on density and vertical distribution of weed seeds in alluvial soil by Adhikary and Ghosh (2014) showing similar trends as that obtained in this experiment at inceptisol. The probable reason for highest weed seed density in zero and reduced tilled plots under weedy check situation may be due to lesser soil disturbance and other micro-environmental changes created by no tillage and crop rotations probably changes selection pressures via change in management. The weed seeds remain on the soil surface or at shallow depth in zero and reduced tillage which got the favourable environmental condition for germination and growth of seedlings. While, tillage operations in conventional till system affects weeds by uprooting, dismembering and burying them deep enough to prevent emergence may be due to far red light accomplishment and so promote or inhibit the weeds' germination and establishment by moving the weed seeds both vertically and horizontally (Swanton *et al*., 2000).

Among the various weed management practices, as expected eco-safe chemical control showed maximum diminution in weed seeds over weedy check (58.38% reduction over initial) at the end of a year, which was followed by botanical control (24.07% reduction over initial); whereas the corresponding figures for physical control (hand weeding) was a slight increasing trend in weed seeds density (3.43%) in comparison to weedy check plots, an increase of 58.24 per cent over initial. The ecosafe chemicals were able to inhibit both monocot and dicot types of weed seeds whereas the botanicals were able to inhibit mostly the monocot weed seeds. Hand weeding restricted the germination of weed seeds in a gradual manner in the experimented crops grown in sequences but the reverse was found in weedy check treatments where deposition of weed seeds in soil were continuing throughout the crops grown in sequence though due to allelochemicals secreted by some weeds may inhibited some weed seeds. Working at Tokyo University of Agriculture, Japan Fuzii (2015) also revealed that plant allele-chemicals have a direct effect on inhibition of many other plants. Findings of Yadav *et al*. (2004) and Gohil *et al*. (2014) also showed similar agreement with the present results.

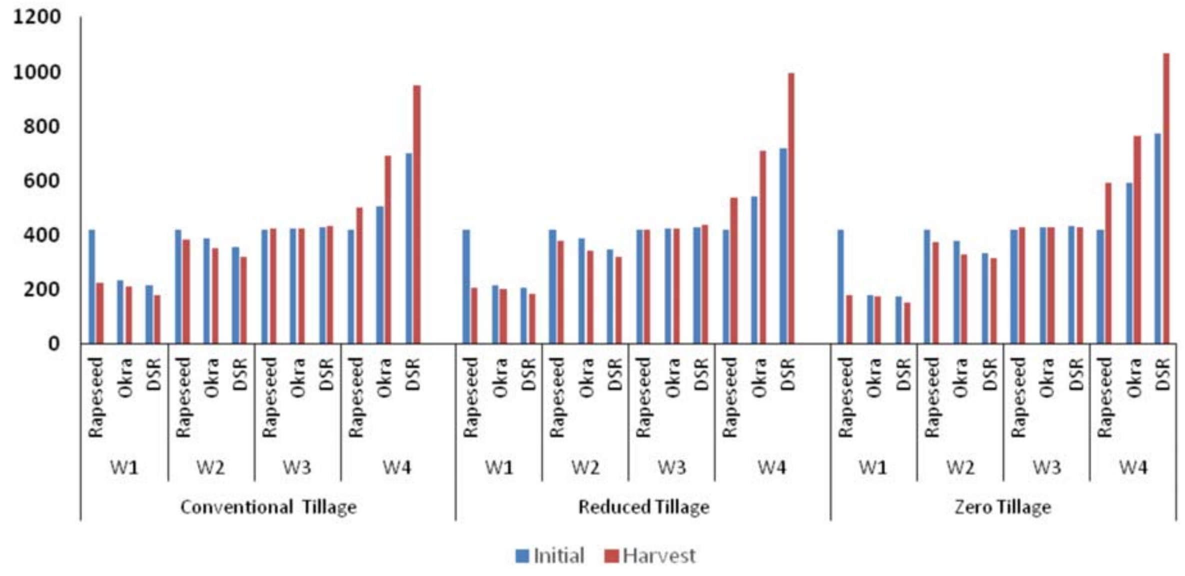
In the experiment 2 and 3 on summer SI rice the results of mixture of botanicals and/or chemical herbicides indicated (Table 2 and 3) that HW at 20 and 40 DAT recorded 69.50 -70.32 per cent WCE along with the maximum yield of 4.76 t ha^{-1} (experiment 2) and 5.26 t ha^{-1} (experiment 3). The treatments of mixture of natural botanicals and synthetic chemical showed

Table 1: Weed seed density m^{-2} in rapeseed –okra – DS rice crop sequence as influenced by tillage and weed management practices during 2014-15

Main-plot	Rapeseed		Okra		DSR	
Treatment	**Initial**	**Harvest**	**Initial**	**Harvest**	**Initial**	**Harvest**
T_1	419.67	384.17	389.75	420.00	425.33	471.50
T_2	419.67	387.58	393.17	421.67	426.83	485.33
T_3	419.67	395.08	396.92	426.00	430.50	492.83
SEm (±)	**3.06**	**3.40**	**3.50**	**2.66**	**4.59**	**6.46**
LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Sub-plot	**Rapeseed**		**Okra**		**DSR**	
Treatment	**Initial**	**Harvest**	**Initial**	**Harvest**	**Initial**	**Harvest**
W_1	419.67	204.89	211.33	197.00	200.89	174.67
W_2	419.67	379.78	385.89	342.78	347.00	318.67
W_3	419.67	425.56	426.78	427.44	430.89	434.56
W_4	419.67	545.56	549.11	723.00	731.44	1005.00
SEm (±)	**4.49**	**5.23**	**5.21**	**4.19**	**6.46**	**8.70**
LSD (0.05)	**NS**	**15.53**	**15.49**	**12.46**	**19.20**	**25.84**

Main plots: ***T_1*** *– Conventional tillage (Two ploughing followed by laddering);* ***T_2*** *– Reduced tillage (One ploughing followed by laddering); and* ***T_3****– Zero tillage (No tillage);* ***Sub plots:W_1****– PRE-chemical herbicide at 1 DAS + Mechanical weeding at 20 DAS;* ***W_2****– PRE-botanical herbicide at 1 DAS + Mechanical weeding at 20 DAS;* ***W_3*** *– Hand weeding at 15 DAS + Mechanical weeding at 30 DAS; and* ***W_4****- Weedy check*

Fig. 1. Weed seed density 100 g soil^{-1} in rapeseed–okra–DS rice crop sequence during 2014-15



W_1*– PE Chemical herbicide at 1 DAS + Mechanical weeding at 20 DAS;* ***W_2****– PE Botanical herbicide at 1 DAS + Mechanical weeding at 20 DAS;* ***W_3*** *– Hand weeding at 15 DAS + Mechanical weeding at 30 DAS; and* ***W_4****- Weedy check*

Table 2: Effect of sole and mixture of botanical (teak and bamboo) and synthetic herbicides on SI rice weed management during Summer, 2016

Treatments	Grain yield ($t\ ha^{-1}$)	WCE (%) at 50 DAT		
		Monocot	Dicot	Total
Sole teak AE at 1 DAT @ 100 ml lit^{-1} water + MW at 30 DAT	3.87	41.16	15.64	28.40
Sole bamboo AE at 1 DAT @ 100 ml lit^{-1} water + MW at 30 DAT	3.67	43.96	8.54	26.25
Sole pretilachlor 30.7 EC at 1 DAT @ 500 g ha^{-1} + MW at 30 DAT	4.24	50.13	46.29	48.21
Mixture of teak AE @ 100 ml + bamboo AE @ 100 ml lit^{-1} water at 1 DAT + MW at 30 DAT	4.05	59.14	22.00	40.57
Mixture of teak AE @ 100 ml lit^{-1} water + pretilachlor 30.7 EC @ 500 g ha^{-1} at 1 DAT + MW at 30 DAT	4.35	61.98	40.16	51.07
Mixture of bamboo AE @ 100 ml lit^{-1} water + pretilachlor 30.7 EC @ 500 g ha^{-1} at 1 DAT + MW at 30 DAT	4.42	63.39	43.38	53.39
Weedy check	3.10	0.00	0.00	0.00
Hand weeding at 20 and 40 DAT	4.76	67.39	71.61	69.50
SEm (±)	**0.139**			
LSD (P=0.05)	**0.413**			

Table 3: Effect of sole and mixture of botanical (*Melilotus* and *Parthenium*) and synthetic herbicides on SI rice weed management during Summer, 2016

Treatments	Grain yield ($t\ ha^{-1}$)	WCE (%) at 50 DAT		
		Monocot	Dicot	Total
Sole *Melilotus alba* AE at 1 DAT @ 100 ml lit^{-1} water +MW at 30 DAT	4.36	54.38	22.96	38.67
Sole *Melilotus alba* AE at 1 DAT @200 $mllit^{-1}$ water +MW at 30 DAT	4.49	58.73	26.38	42.56
Sole *Parthenium hysterophorus* AE at 1 DAT @ 100 ml lit^{-1} water + MW at 30 DAT	3.67	53.41	21.59	37.50
Sole *Parthenium hysterophorus* AE at 1 DAT @ 200 ml lit^{-1} water + MW at 30 DAT	4.01	59.64	27.42	43.53
Sole pretilachlor 30.7 EC at 1 DAT @ 500 g ha^{-1} + MW at 30 DAT	4.55	50.25	49.51	49.88
Mixture of *Melilotus alba* + *Parthenium hysterophorus* AEat 1 DAT @100 $mllit^{-1}$ water + MW at 30 DAT	4.73	60.82	30.28	45.55
Mixture of *Melilotus alba* + *Parthenium hysterophorus* AE@ 200 $mllit^{-1}$ water at 1 DAT+ MW at 30 DAT	4.61	67.69	31.97	49.83
Mixture of *Melilotus alba* AE @ 100 ml lit^{-1} water + Pretilachlor 30.7 EC @ 500 g ha^{-1} at 1 DAT+ MW at 30 DAT	5.04	69.38	52.44	60.91
Mixture of *Parthenium hysterophorus* AE @ 100 ml lit^{-1} + pretilachlor @ 500 gha^{-1} at 1 DAT+ MW at 30 DAT	4.94	70.47	49.43	59.95
Weedy check	3.28	0	0	0
Hand weeding at 20 and 40 DAT	5.26	72.34	68.31	70.32
SEm (±)	**0.027**			
LSD (0.05)	**0.080**			

better weed management (WCE ranged 51.07-53.39 % in experiment 2 and 59.95-60.91% in experiment 3) over the mixture of only botanicals (WCE 40.57 % in experiment 2 and 45.55-49.83 % in experiment 3) or sole application of botanicals or synthetic chemicals (WCE in experiment 2 ranged 26.25-48.21% and in experiment 3 ranged 37.50-49.88%). The grain yield data showed similar trends, the mixture between natural botanicals and synthetic chemical recorded 8.27, 3.42, 16.31 and 41.45 % more yield over the mixture of only botanicals, sole application of chemical, sole application of botanicals and weedy check, respectively in experiment 2 while the corresponding figures for experiment 3 were 6.85, 9.67, 21.06 and 52.13 per cent. The reason of lowering the weed competition in paddy crop during its' critical crop weed competition period (CCWCP) and increasing the productivity of SI paddy by using APWM may be due to reduction of weed seed bank before the rice planting and further using mixture of natural botanicals and synthetic chemicals at PE may be due to their synergistic effect further inhibition of the germinated weeds that able to create an identical apposite eco safe environment favorable for snowballing both the soil and the paddy crop health.

In pilot trials of potato and mustard at 20 DAP / DAS the mixture of natural botanicals and synthetic chemicals also showed better WCE in comparison to their sole application. Paraquat dichloride, a nonselective contact synthetic herbicides is able to kill all the visible weeds in the upper surface besides inhibited germination of weed seeds in the 0-10 cm under surface soil and the natural allelochemicals of either bamboo or cucumber is able to inhibited mostly both the grassy weed seeds and plants and thus their mixture showed better weed management in both crops potato and mustard. Further may be because of the synergistic effect of both the natural and synthetic chemicals the density of weed pests were lower in this treatments. The allelochemicals present in tea leaves also showed similar inhibition effects on weed plant management may be due to presence of phenolic compounds like all other plant extracts. Neither the soil microflora prominence showed inconvenient for soil nutrient availability in CCWCP nor any significant influence on seedling establishment as against botanical treatments or for mixture of botanicals and synthetic chemicals treatments as compared to sole chemical treatments for weed management in both two main experiments and three pilot trials. Asthini (2008) and Chen (2009) also found similar inhibition effects of *Eucalyptus* and *Parthenium* extracts on growth and germination of different weeds.

From these experiments, it could be concluded that reducing seed bank before crop planting and using PE mixture of botanical and synthetic chemical herbicide following a mechanical weeding (annual planning of weed management) is, therefore able to increase crop productivity by gradual reducing weed pest losses and increasing soil health status as it is a part of biological management in system intensification methodology. Farmers' improve thinking through the awareness of using diversification of crops with cover legumes, developing of rural centric marketing facility by government, establishing small Krishi industries at interior rural areas by government and NGOs and more interaction involving scientists with stake holders to sort out krishi problems, are the prime factors with this best management practices of available resources along with APWPM for enhancing the productivity and to reach the target of sustainable eco efficient food security.

REFERENCES

Adhikary P. and Ghosh R. K. 2014. Effects of cropping sequence and weed management on density and vertical distribution of weed seeds in alluvial soil. *J. Crop Weed.* **10** : pp. 504-507

Asthini, AN. 2008. The effects of methanolic extract of *Eucalyptus cameldulensis* Dehnh.on growth and germination rates of *Chenopodium album* L. *Indian J. Med. Aromatic Pl.* **24** : 293-303.

Cardina J., Herms C.P. and Doohan D.J. 2002. Crop rotation and tillage systems effects on weed seedbanks. *Weed Sci.* **50** : 448-60.

Caroca R.P., Candia P.S. and Hinojosa E.A. 2011. Characterization of the weed seed bank in zero and conventional tillage in Central Chile. *Chilean J. Agric. Res.* **71** : 140-47.

Chauhan B., Gill G. and Preston C.2006.Influence of tillage system on vertical distribution, seedling recruitment and persistence of rigid ryegrass (*Lolium rigidorum*) seed bank. *Weed Sci.* **54**: 669-76.

Chen. 2009. Allelopathy of leaves of *Parthenium hysterophorus* L on *Abuliton theophrasti* and *Echinochloa crusgalli* (L) Beauv. *Acta-Phytophylacica* **36** : 77-81.

Directorate of Weed Science Research (DWSR), ICAR. 2010; *Technical Extension Bulletin.*

Forcella F, Webster T and Cardinal J. 2011. Protocols for weed seed bank determination in ago-ecosystems, *FAO Corporate Document Repository* (http://www.fao.org/docrep/006/ Y5031E/y5031e03.htm1/12)

Fujii Yoshiharu. 2015. Allelochemicals and natural products from weeds. Int. Con. on "Weed Science for Sustainable Agriculture, Environment and Biodiversity, 13-16th October, 2015 at Hyderabad, India. Extended Summary pp. 41

Ghosh R. K, Sentharagai S. and Shamurailatpam D. 2014. SRI – A Methodology for substantially raising rice productivity by using farmers' improve thinking and practice with farmers' available resources. *J.Crop Weed* **10** : 4-9.

Ghosh R.K, Shamurailatpam D,Ghosh A, Sentharagai S, Labar A, Nongmaithem D, Jana P.K., Ghosh S. and Kole R.K. 2015. Prospects of botanical herbicides in system intensification. *Indian J.Weed Sci.***47** : 401–407.

Gohil B.S, Mathukia R.K, Dobariya V.K and Chhodavadia S.K. 2014. Potential of weed seedbank dynamics and economic feasibility of weed management practices in rabi fennel (*Foeniculum vulgare* Mill.). *World Res. J. Agric. Sci.***1**(1): 2-6.

Murphy S.D, Clements D.R, Belaoussoff S, Kevan P.G and Swanton C.J. 2006. Promotion of weed diversity and reduction of weed seedbanks with conservation tillage and crop rotation. *Weed Sci.***54** : 69-77.

Rahman A, James T.K., Grbavac N and Mellsop J. 1995. Evaluation of two methods for enumerating the soil weed seed bank. *Proc. 48th N.Z. Pl. Prot. Conf*. **48**: 175-80.

Rahman A, James T.K., Waller J.E. and Grbavac N. 1997. Soil sampling studies for estimationof weed seedbanks. *Proc. 50thN.Z. Pl. Prot. Conf*. **50** : 447-52

Sosnoskie L.M, Hermes C.P. and Cardina J., 2006. Weed seedbank community composition in a 35-yr-old tillage and rotation experiment. *Weed Sci*. **54**:263-73.

Swanton C.J., Shrestha A, Knezevic S.Z., Roy R.C. and Ball-Coelho B.R. 2000. Influence of tillage type on verticalweed seedbank distribution in a sandy soil. *Canadian J. Pl. Sci.* **80**:455-57.

Uphoff N. 1999. Agro-ecological implications of the system of rice intensification. *Env., Dev. Sustainability* **1** : 297-13.

Yadav R.S, Sharma S.K, Poonia B.L, and Dahama A.K. 2004. Selectivity and phytotoxicity of oxadiargyl on cumin and weeds and its residual effect on succeeding moth bean and pearl millet. *Indian J. Weed Sci*. **36** : 83-85.