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Validation and implementation of principles of the Integrated Pest Management concept – sustainability and current challenges in pest endemic pulse bowl of India

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ABSTRACT

Insect pests and vascular diseases are the major constraints to pigeonpea production in Karnataka and primarily responsible for lower productivity. There is no substantial host plant resistance to key insect pests in currently adopted cultivars, however effective utilization of other components of pest management led to development of various integrated pest management (IPM) to minimize yield losses and protect the environment. In present studies, it is a total "system approach" to sustainable pest management involving seed treatment with microbials, synchronized sowing, modification in landscape and application of need-based pesticide spray. Spray schedule was combined with online pest monitoring system for the plant protection related advisories for the target region. The resultant IPM package implemented through farmer-managed operational scale plots and compared with non-IPM (normal farmer practices) across 7 taluks of Gulbarga district for 4 years (2010–2013 seasons). A total of 2197 farmer-managed demonstrations were conducted, giving a 5–104% yield advantage (district means) of IPM over farmers' practice. Pest incidence data in IPM vis-à-vis non-IPM clearly indicates that pest can be managed by adopting IPM technology. Number of spray of pesticides could be reduced from 6 to 4. Pesticide residue analysis for 102 chemical pesticides for representative soil, water and grain samples drawn from IPM as well as non-IPM (farmers' practice) fields, indicates their presence within the prescribed limits. Grain yields in IPM plots were generally 15–20% higher than in FP. Even with all the available inputs, the production is subject to residual production risk due to abiotic constraints (rainfall), diseases and insect pests, which often large farmers are able to bear. Here in present studies it has been clearly demonstrated that strategies are friendly and adoptable by the small and marginal farmers. Effective implementation of IPM practices by participating farmers demonstrated that remunerative and reliable yields could be obtained in this pest-prone environment and helps mitigate climate induced threat to agricultural development having relevance to other pigeonpea growing regions prone to similar pest pests.

Key words: EIQ, IPM, Pigeonpea, Plant protection, Pod borer management

Pigeonpea [*Cajanus cajan* (L.) Millsp.] is an important pulse crop in semi-arid tropics and sub-tropical areas of the world with 75% being produced in India. Gulbarga district is identified as pulse bowl of Karnataka state accounting 3.50 to 3.75 lakh ha of area with average production of 850 kg/ha per unit area, with a scope to increase it to 1200 kg/ha. A number of factors limit achieving potential yields, wherein insects play a major decisive role in reducing the yield. Though more than 250 species of insects have been reported on pigeonpea by Lateef and Reed (1990), from which only a few cause significant and consistent damage to crop. Amongst insect pests, pod borer (*Helicoverpa armigera* Hubner*),* spotted bollworm (*Maruca vitrata* Fabricius) and pod fly (*Melanagromyza obtusa* Malloch.) infestation has assumed a special significance due to their widespread occurrence and economic loss to the crop (Shanower *et al.* 1999). Other important constraints contributing to the reduction in yield are root wilt (*Fusarium udum* Butler), Phytopthora rot (*Phytopthora drechsleri* f. sp. *cajani* Tucker), sterility mosaic disease (SMD) and cercospora leaf spot (*Cercospora indica* U.B. Singh) disease. Nevertheless, it remains an economic crop and ever-increasing imports are required to meet domestic demand. Deficit in production and supply has led to increase in use of chemical pesticides as therapeutic approach of killing pest on calendar based schedule, often reducing the benefit ratio apart from unreported harm to environment and to naturally

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occurring beneficials. Amongst farmers there is a general lack of knowledge of the negative impacts of pesticides on the production, economy and environment. Component research has led to identification of mitigation measures against, e.g. low levels of host plant resistance, which can be compensated through judicious use of pesticides through community approach (Bhede *et al.* 2015). Available resistance resources are effective in minimizing *Fusarium* wilt with limited success in *Phytopthora* and sterility mosaic disease due to their epidemiology. Other diseases like *Cercospora* leaf spot and powdery mildew needs to be managed through timely application of fungicides. In Maharashtra, effectiveness of integrated pest management (IPM) strategies could be qualitatively evaluated and demonstrated in farmers' participatory mode (Sharma *et al.* 2015, Sharma *et al.* 2011, Gopali *et al.* 2010). Elsewhere, partial success of implementing IPM for managing pod borer has also been demonstrated (Chaudhary *et al*. 2008, Samiayyan and Gajendran 2009, Srinivasan and Sridhar 2008, Hanumanthaswamy *et al*. 2009, Nagamani *et al*. 2013), however conventional farmers' practices could not succeed due to constraint of resistance in *Helicoverpa* against major insecticides (Kranthi *et al.* 2002).

Review indicates that, pest research has been largely dominated by insect bias, with disease in second place and nematodes as well as weed third. Hence, in present study the research has been broadened in proportion to damage at field level with focus on IPM techniques without any bias either to pest or chemical pesticides. IPM strategies were formulated, wherein mitigation measures to the major constraints were combined to increase productivity and to make production sustainable, demonstration-cum-validation of IPM strategies were implemented in *kharif* seasons 2010 to 2013 in farmers' participatory mode with a goal to reduce level of incidence of pests and facilitate farmer to adopt strategies to increase yields.

MATERIALS AND METHODS

On the contrary to therapeutic calender based spray schedule, our pest management efforts concentrated on effective, safe and economically accepted alternatives (Lewis *et al.* 1997, Sharma *et al*. 2015) and this led to implementation of IPM in the area-wide mode covering 7 blocks (taluks) of Gulbarga district, viz. Chittapur, Gulbarga, Jewargi, Chincholli, Aland, Afzalpur and Sedam. To encourage wider adoption, it was implemented in farmer's participatory mode (Lilja and Ashby 2000, Okali *et al*. 1994, Sharma *et al*. 2015) using infrastructure of Agricultural Research Station, Gulbarga and financial support from Government of India under National Food Security Mission during 2010-14. IPM strategies focused on the first and most fundamental line of defense against pests and diseases to maintain a healthy agro-ecosystem, accordingly validated components were implemented in 24300 ha, benefiting 2197 farmers belonging to 112 villages. We believed that implementation in farmers' participation mode will restore the confidence level and enhance capacity to adopt need-based application of appropriate pesticides leading to conservation of beneficial insects and economic benefits. Plant protection strategies were based on holistic approach coupled with monitoring of pest and use of Information and Communication Technology (ICT) for relaying pest advisories (www.farmer.gov.in). The IPM strategies utilised pest resistant/tolerant varieties (TSR-3, BSMR-736 and ICPL-8863) treated with local strain of bio-fertillizer, viz. *Rhizobium* (500 g/15 kg seed), phosphate solubilising bacteria (PSB) (500 g/15 kg seed) and microbial bio-pesticide [*Trichoderma viride* (cfu 2×10^6)] @ 10 g/kg of seeds for seed treatment. $ZnSO_4$ @ 25 kg/ha and elemental sulfur @ 20 kg/ha were applied in the fields to take care of nutrient deficiency, as they have proved to increase yield significantly (Deshbhratar *et al.* 2010, Jat and Allahawat 2010, Sharma *et al*. 2012).

Farmers field schools (FFS) were regularly held at fortnightly interval to educate on identification and distinguishing friendly and foe insects to make them decision maker of their own farms (Sharma *et al*. 2001). Based on regular field visits and monitoring of adult moth catches through pheromone traps, incidence were recorded on weekly basis for spotted pod borer, pod borer (*H armigera.*), pod fly (*M obtuse*.), predators (*Coccinella transversalis* and *Chrysoperla carnea*) and parasitoids (*Telenomus* spp and *Cotesia* spp). Pest advisories based on real time pest/defender information and Economic Threshold Level (ETL), farmers were sent through SMS on their registered mobile. Advisories were focused on use of eco-friendly pesticides (spinosad 45SC (0.1 ml/l), indoxacarb 14.5SC (0.3 ml/l), emamectin benzoate 5 SG (0.2 g/l), flubendiamide 48SC (0.075 ml/l), chlorantraniliprole 18.5 SC @ 0.15 ml/l) and IGR's (Babriya *et al.* 2010, Mandal and Mishra 2003, Meena *et al*. 2006, Srinivasan and Durairaj 2007 and Sreekanth *et al*. 2014). Farmers were educated on benefits of using chemical pesticides having a label claim with correct dosage and at right stage. Uses of new molecules with broad spectrum insecticides in rotation were advised to mitigate and reduce the resistance problem as well as outbreak of secondary pests, viz. maruca, podbugs and podfly, which are on increase. As a result different classes of chemical insecticides were recommended to manage the above-mentioned pests based on previous year experience (Gopali 1998, Gopali *et al*. 2010, Sharma *et al*. 2010, Sharma *et al*. 2011). The ovicides were sprayed first, followed by botanicals (Neem oil 3000 ppm; 0.03% Azarictin), microbials (HaNPV 1×10^9 POB/mL) and then green chemistry molecules (Emamectin benzoate 5% SG and chlorantraniliprole 18.5% SC). Going a step further, we estimated impact of pesticidal use on consumer as well as on ecosystem based on the data of chemical pesticides and number of sprays carried out on IPM and non-IPM (farmers' practice) fields. Taking the EIQ value for the active ingredients, the proportion of pesticides used in the field was calculated as per method described by Kovach *et al*. (1992) and value of the "environmental impact (EI)" in the field was obtained. Environmental impact quotient (EIQ) of used pesticides were compared to generate awareness about the harmful effects of pesticides on environment, and the environmental benefits incurred by IPM done as per the method used in IPM programs in Virginia (Mullen *et al*. 1996). The data were subjected to unpaired t-test analysis, wherein villages served as replication for their statistical interpretation.

RESULTS AND DISCUSSION

Majority of farmers of Gulbarga, grew pigeonpea as sole crop, barring few pockets wherein it is intercropped with pearl millet or sunflower (Nath *et al.* 2008). Physical monitoring of crop through FFS and adult catches in pheromone trap on weekly basis provided the real time information on population of pest vis-à-vis defenders forming the basis for implementation of IPM strategies. It formed basis for issue of advisories to the growers to initiate protective sprays at farmers' level. The pheromone trap catches vis-à-vis larval population coincided with flowering stage (mid September) at majority of locations. The egg load (number of eggs)/plant, recorded at three crop stages, viz. 50% flowering, at peak flowering as well as at pod development stage (Table 1) indicates that for all the 4 years, egg population was less in the IPM in comparison to non-IPM at initial stages of crop. However, population at pod development stage was not statistically different. The larval population count at all 3 crop stages indicated effectiveness of IPM in comparison to non-IPM (Table 2). The average larval population of seven (7) taluks as well as its population trend in non-IPM over 4 years indicated higher population in 2010 and 2011 with gradual decrease thereafter. Four year experience indicates that replacement of traditional pesticides with modern chemistry and molecular biology has helped in suppressing podborer in general, which continues to exist in fields as potential threat.

Of late due to shift in rainfall pattern as well as presence of multiple cultivars with indeterminate flowering characteristics led to increase in incidence of spotted bollworm. Number of live web/plant were recorded at peak flowering as well as at pod development stage (Table 3), indicates that IPM strategies led to lesser webs for all the 4 years in comparison to non-IPM. The data on incidence at pod development stage are not significantly different apparently due to non-availability of susceptible stage. Podfly continues to be a problem, hence destructive sampling and analysis of immature pods indicates that except for year 2012, incidence level in IPM fields were significant different from non-IPM (Table 4).

Percentage incidence of sterility mosaic disease (PPSMV) clearly indicates that it continues to be a major field disease due to cultivation of local varieties with culinary preference. The incidence data in IPM for different years was significantly different from non-IPM, indicating that varietal replacement proved effective and economical. At certain places dicofol @ 2 ml/l was used but restricted to limited areas. Incidence of *Cercospora* leaf spot diseases causing flower as well as leaf drops in different taluks indicates its regular occurrence with increasing trend for a very short period. IPM strategies based on therapeutic use of fungicides could control disease as evident from the significant incidence difference in IPM and non-IPM

Table 1 Egg load of *H armigera* in IPM as well as non-IPM demonstration blocks of Gulbarga district

Particulars	Mean number of pod borer, egg load/plant														
	At 50% Flowering stage of crop					At peak flowering stage of crop					At pod development stage of crop				
	2010	2011	2012	2013	Mean	2010	2011	2012	2013	Mean	2010	2011	2012	2013	Mean
IPM	0.33_a	0.29_a	0.30_a	0.43_a	0.34_a	1.16 a	1.07_a	0.74_a	0.57_a	0.89_a	0.16_a	0.12_a	0.18_a	0.26_a	0.18_a
Non-IPM	2.26_b	2.14_b	1.73_b	1.62_b	1.94_b	2.54 b	2.27_b	1.82_b	1.47_b	2.03_b	0.16_a	0.14_a	0.17_a	0.23_a	0.18_a
CD (P=0.05)	0.28	0.30	0.30	0.29		0.28	0.28	0.28	0.28		NS	NS	NS	0.02	

Table 2 Larval population of *H armigera* in IPM as well as non-IPM demonstration blocks of Gulbarga district

Particulars	Mean number of pod borer larvae/plant														
	At 50% flowering stage of crop					At peak flowering stage of crop					At pod development stage of crop				
	2010	2011	2012	2013	Mean	2010	2011	2012	2013	Mean	2010	2011	2012	2013	Mean
IPM	0.27_a	0.28_a	0.32_{bc}	0.55_a	0.35a	0.96_a	0.87_{cd}	0.77_a	0.81_a	0.85 a	0.31_a	0.26_a	0.27_a	0.42_a	0.31 a
Non-IPM	0.39_b	0.42_b	0.44	1.05_b	0.58 b	2.16_b	1.71_b	1.63_b	1.39_b	1.72 b	2.31_b	1.90_b	1.63_b	1.54_b	1.84 b
CD (P=0.05)	0.04	0.05	0.05	0.04	0.05	0.06	0.25	0.06	0.05	0.04	0.09	0.06	0.04	0.04	0.05

Table 3 Status of spotted pod borer live webs in IPM non IPM demonstration blocks of Gulbarga district

Particulars	Mean number of spotted pod borer live webs/plant									
	At peak flowering stage of crop					At pod development stage				
	2010	2011	2012	2013	Mean	2010	2011	2012	2013	Mean
IPM	0.27_a	0.12_a	0.09_a	0.08_a	0.14	0.02_a	0.05_a	0.08_a	0.09_a	0.06
Non-IPM	0.06_b	0.54_b	0.37_b	0.25_b	0.56	0.06_b	0.05_a	0.07_a	0.07_a	0.07
CD (P=0.05)	0.004	0.028	0.024	0.002		0.027	NS	NS	NS	

Table 4 Status of pod fly damage in IPM as well as non-IPM demonstration blocks of Gulbarga district

Particulars	Per cent pod fly damage (% Seed damage)									
	At pod development stage of crop					At harvesting stage of crop				
	2010	2011	2012	2013	Mean	2010	2011	2012	2013	Mean
IPM	3.30_b	2.60_b	2.93_b	2.24_a	2.77	4.10_a	3.50_a	3.93_a	3.09_a	3.66
Non-IPM	1.50_a	2.40_a	4.96_b	2.80_b	2.92	14.30_b	18.10_b	13.48_b	6.77_b	13.16
CD (P=0.05)	0.10	0.26	0.09	0.18		0.45	0.47	0.47	0.06	

Table 5 Incidence of sterility mosaic and cercospora leaf spot diseases in different taluks of Gulbarga district

Particulars	Sterility mosaic disease (%)					Cercospora leaf spot disease (%)				
	2010	2011	2012	2013	Mean	2010	2011	2012	2013	Mean
IPM	7.94_a	5.97_a	5.74_a	4.79_a	6.11	2.44_a	1.00_a	1.95_a	1.47_a	1.86
Non-IPM	23.6_b	17.4_b	8.21_b	6.23_b	13.86	4.83_b	1.66_b	2.84_b	3.60_b	3.23
CD (P=0.05)	0.365	0.568	0.049	0.59		0.01	0.23	0.30	0.441	

(Table 5).

The study has consequently indicated that the incidence of *Helicoverpa, Maruca, Melanagromyza*, PPSMV and cercospora leaf spot could be significantly lowered in IPM and its impact could help in increasing yield from average of 860 to 1009 kg/ha (Table 6). The survey of IPM and conventional farmers carried out in each selected district, revealed a difference in production costs and environmental impacts of these two agricultural technologies. The analysis of production cost revealed a benefit of 15% on adopting IPM technology. The users of IPM technology were benefited due to lower use of pesticides (insecticides and fungicides).

Despite uniform IPM strategies, level of pest incidence (pod damage) varied in different taluks, however it was significantly less in IPM fields (Table 6). Difference in incidence can be attributed to the varieties and local climate which might have influenced the crop and pest. The present IPM strategies could also lead to the use of appropriate dose of pesticides at the correct stage (50% flowering) reducing the number of sprays as well as amount of pesticides (Table 9). A close collaboration between farmers and pest scouts served as the key factor enabling the successful implementation of present IPM programme. A similar impact of monitoring on pesticide reduction has been reported from Australia (McDougall 2006, Sharma *et al*. 2015).

The effectiveness of profenofos (50% EC), chlorantraniliprole (18.5% SC), emamectin benzoate (5% SG), indoxacarb (15.8% EC) and flubendiamide (39.35% EC) was high and popular among farmers (Neharkar *et al.* 1999) in general, as also reported by other researchers (Dodia *et al*. 2009, Meena *et al*. 2006, Srinivasan and Durairaj 2007, Mittal and Ujagir 2005, Singh *et al.* 2009, Chandrakar and Shrivastava 2002, Reed 1965, Sharma *et al.* 2011). Plant product, neem oil (3000 to 5000 ppm), etc. have also been used besides *Ha*NPV (1×10^9 POB/mL) and found effective in minimizing crop losses. A comparison of IPM strategies with conventional growers has showed different usage pattern of pesticides (Table 9**.** Prior to initiation of IPM activities, farmers use to spray indiscriminately and the number use to vary from 5 to 8 calendar applications of organophosphates and pyrethroids per crop which has been brought down from 2 to 3 application. In subsequent years some of the non-IPM farmers also adopted IPM strategies, especially green molecules (emamectin benzoate 5% SG and chlorantraniliprole 18.5% SC). Additional information collected on the quantity, number of pesticidal sprays and class of pesticides for each block revealed a significant reduction in use since 2008 and an improvement in terms of environmental impact quotient (EIQ). This can be attributed to fewer sick fields treated for pod borer incidence with new molecules by majority of farmers. During 2010-13, the pesticide use was driven by the availability of new molecules, especially chlorantraniliprole (18.5% SC), indoxacarb (15.8% EC), emamectin benzoate (5% SG) and flubendiamide (39.35% EC).

The present findings clearly indicate that the new generation insecticides chlorantraniliprole (18.5% SC), flubendiamide (39.355 EC), indoxacarb (15.8% EC) and emamectin benzoate (5% SG) proved quite effective against pod borer, *H. armigera* leading to higher crop yield. Further, the cost benefit ratio was also more with these green molecules. Hence, it is suggested that these effective

Table 6 Influence of IPM on pod damage and yield of pigeonpea under demonstration at Gulbarga District

Particulars	Pod damage (%)					Yield/ha (in kg)				
	2010	2011	2012	2013	Mean	2010	2011	2012	2013	Mean
IPM	6.19_a	5.12 a	4.66_a	5.95_a	5.48	1000_a	825_a	1150_a	1060_a	1010
Non-IPM	13.67_b	11.51_b	10.56_b	11.12_b	11.71	875_b	750_b	925_b	915_b	860
CD (P=0.05)	0.389	0.245	0.215	0.29		66	57	72	67	

Table 7 Grain yield of pigeonpea crop under IPM in comparison to Karnataka and national average

Particulars	2010	2011	2012	2013	Average
IPM average yield (kg/ha)	1000	825	1150	1060	1009
Non - IPM average yield (kg/ha)	875	750	925	915	866
IPM v/s non-IPM (% increase in yield)	14.3	10.0	24.3	15.8	16.5
Karnataka State average (kg/ha)	477	487	467	471	473
% increase over state average	109.6	72.9	146.3	125.1	113.5
National average (kg/ha)	723	712	656	686	697
% increase over national average	38.31	14.11	75.30	54.52	45.56

Table 8 Cost, returns and benefit of pigeonpea crop under IPM v/s non IPM

Particulars	2010-11		2011-12		2012-13		2013-14	
	IPM	Non-IPM	IPM	Non-IPM	IPM	Non-IPM	IPM	Non-IPM
Yield (kg/ha)	1000	875	825	705	1075	925	106	915
Gross return (₹)	40000	35000	33000	28200	43000	37000	47700	41175
Cost of plant protection (₹)	3115	4200	2860	3740	4575	5275	3176	5275
Other costs (₹)	10385	10885	10385	10885	10831	10825	10800	9800
Total cost (₹)	13500	15085	13245	14625	15406	16100	13245	14625
Net return (₹)	26500	19915	19755	13575	27594	20900	34455	26550
B:C ratio	2.96	2.32	2.49	1.93	2.79	2.30	3.60	2.82
Ave. market price (₹/kg)	40.00		40.00		40.00		45.00	

B: C = Benefit : cost ratio

insecticides may be alternated in order to avoid/delay the development of resistance. Finally, the EIQ calculations for 4 years indicates significant difference in pesticide use by the adopter and non-adopter IPM farmers. Field use rating of EIQ was also calculated and is presented in Table 9. The lower values of EIQ in IPM adopters clearly indicate the effectiveness of IPM technology in reduction of overall application of pesticides. EI analysis for each district has also demonstrated a significant reduction in environmental impact due to combined strategies adopted under IPM technology. It also confirmed that EI values can be effectively used as a decision support tool for the selection of pesticides that are less hazardous to use in the absence of botanical/microbial alternatives. The large scale testing has proved that IPM technology has potential to increase yield and reduced the cost of production. The overall achievement in the implementation of IPM technology has revealed that small-scale farming is more efficient, because of consolidated efforts in the precise management of manageable areas under their control. Thus, IPM is a smallholders-friendly technology.

Considering economic impact of IPM, the yield levels of pigeonpea increased by 45.5% as compared to national average yield levels (Table 7), and farmers have expressed satisfaction for the technology given to them as and when they needed, e.g. importance of micronutrients especially Zn and Sulphur due to increased yield with quality grain production; use of bio-fertilizers (*Rhizobium* and PSB) and bio-fungicides (*Trichoderma*) as evident from healthy plant stands; farmers to identify the pest at egg stage and early instars larvae of *Helicoverpa* in pigeonpea on buds, flowers, and pods and helped to manage the pest at early stage. In few pockets the seedling mortality caused by *F verrucosa* was observed, to which native *Trichoderma* were ineffective as proven by in-vitro studies. Promotion of TS3-R, was well accepted due to its early maturity and resistant to wilt disease prevalent in field soil. ICT based communication systems and networks of pest scouts provided options for disseminating IPM information to farmers over their mobile. Feedback studies suggests that farmers cared most because advisories were brief and easily understood, came from credible and relevant sources that too at critical junctures in decision-making time and helped them to implement action plans that are economically feasible. This could prevent routine calendar-based spray being used by the farmers. Farmers have acquired the knowledge on new molecules and judicious use of conventional insecticides and their effectiveness against different insect pests. Implementation of monitoring-based IPM together with demonstration led to the use of appropriate pesticides and reduction in the number of applications (Table 10). Its wide adoption resulted in 25-40% reduction in pesticide pressure on environment and save revenue worth of 25 to 40 crores to the farming community in Gulbarga district. Yield increased due to adoption of IPM due to right use of chemical at right time with right equipment with minimal toxic usage in the pulse ecosystem. The technology on Integrated Pest Management (IPM) technology consisting of new molecules, botanicals (NSKE5%) and microbial agent (HaNPV) has been understood for the management of podborer. INM and IPM resulted in healthy environment for human being, for pest defenders (Bhoyar *et al.* 2004, Bhede *et al.* 2014) as well as for restoring soil health, which in long run reduce dependence on chemical nitrogenous fertilizers. The results

Table 9 Calculation of environmental impact (EI) on farmers' field at Gulbarga (Karnataka) using IPM technology compared with the conventional practices during 2010-12

Technology	Pesticide	Quantity/ha	Application/No	EIQ	Consumer	Worker	Ecological	EIQ/ha
Gulbarga 2010-11								
IPM	Neem oil	1500 ml	1	12.1	0.1	0.2	0.6	0.3
	HaNPV	450 LE	1	0	0	0	0	0
	Profenophos	2000 ml	1	59.5	2.6	6.9	143.2	50.9
	Dimethoate	500 ml	1	33.5	1.5	1.3	10.1	4.3
	Chlorantraniliprole	150 ml	1					
	Total		5	105.1	4.2	8.4	153.9	55.5
FP	Chlorpyriphos	1000 ml	1	26.9	0.7	2.1	24.8	26.9
	DDVP	250 ml	1	53.3	2.9	6.7	16.4	8.7
	Methomyl	300 ml	1	22	1.1	0.6	5.0	2.3
	Dimethoate	500 ml	1	33.5	1.5	1.3	10.1	4.3
	Indoxacarb	500 ml	1	31.2	0.2	0.4	5.2	1.9
	Spinosad	200 ml	1	14.4	0.2	0.5	2.7	1.1
	Acephate	1000 ml	1	24.9	8.4	10.0	31.5	16.6
	Emamectin benzoate	200g	1	26.3	0.0	0.1	0.6	0.2
	Total		8	232.5	15	21.7	96.3	62
Gulbarga 2011-12								
IPM	HaNPV	450 LE	1	0	0	0	0	0
	Neem oil	1500 ml	1	12.1	0.1	0.2	0.6	0.3
	Dimethoate	500 ml	1	33.5	1.5	1.3	10.1	4.3
	Chlorantraniliprole	150 ml	1					
	Total		4	45.6	1.6	1.5	10.7	4.6
FP	Monocrotophos	550 ml	2					
	Chlorpyriphos	1000 ml	1	26.9	0.7	2.1	24.8	26.9
	Indoxacarb	500 ml	1	31.2	0.2	0.4	5.2	1.9
	Spinosad	200 ml	1	14.4	0.2	0.5	2.7	1.1
	Quinolphos	1000 ml	1	42.9	4.3	4.4	18.8	9.2
	Cypermethrin	150 ml	1	36.4	0.2	0.4	2.9	1.2
	Emamectin benzoate	200 g	1	26.3	0.0	0.1	0.6	0.2
	Total		8	178.1	5.6	7.9	55	40.5

Table 10 Level of pesticide residues detected in soils of pigeonpea fields at Gulbarga

Soil (Pigeonpea)	IPM				Non-IPM			
	% occurrence	Ave	Extreme	MRL	% occurrence	Ave	Extreme	MRL
Azole	3.57	1.97	1.97		1.79	0.01	0.01	
Anthranilic	3.57	0.02	0.02		0.00	0.00	0.00	0.00
Benzimidazole	3.57	0.09	0.09	0.05	3.57	0.03	(0.01-0.05	0.05
Benzoylurea	0.00	0.00	0.00	0.00	1.79	0.02	0.02	
Organochlorine	0.00	0.00	0.00	0.00	7.14	0.08	(0.03-0.11)	
Organophosphate	78.57	0.11	(0.04-0.22)	4.00	51.79	0.14	(0.01-0.96)	4.00
Phenol derivatives	10.71	0.02	(0.02-0.03)		12.50	0.03	(0.01-0.08)	
Pyrethroid	0.00	0.00	0.00	0.00	21.43	0.22	(0.01-1.40)	Nil

Table 11 Status of pesticide residues in grains of pigeonpea collected from fields at Gulbarga

Grains (Pigeonpea)	IPM				Non-IPM			
	% occurrence	Average	Extreme	MRL	% occurrence	Average	Extreme	MRL
Azole	5.13	0.04	(0.01-0.07)		6.90	0.01	0.01	
Bendimidazole	11.54	0.04	(0.01-0.16)	0.05	3.45	0.02	0.02	0.05
Organophosphate	53.85	0.66	(0.01-10.87)	4.00	58.62	0.05	(0.01-0.14)	4.00
Phenol derivatives	17.95	0.42	(0.03-1.70)		17.24	0.01	(0.01-0.02)	
BDL	0.00	0.00	0.00	0.00	13.79	0.00	0.00	
Unclassified	3.85	0.32	(0.01-0.93)		0.00	0.00	0.00	
Coumarin	2.56	0.03	(0.02-0.03)		0.00	0.00	0.00	
Macrocyclic lactone	2.56	0.01	0.01		0.00	0.00	0.00	
Neonicotinoid	2.56	0.10	(0.02-0.17)		0.00	0.00	0.00	

of the farmer participatory approaches have been found to be very encouraging and apparently farmer awareness is undergoing massive sweep as evident through the enormous reduction in the usage of pesticides in Gulbarga districts by implementing the IPM under government programme. Above said findings has reemphasised importance of broader based ecosystem management as propagated by Altieri (1995) and proved helpful in mitigation problems encountered with conventional pesticides, e.g. toxic residues, pest resistance, secondary pest and pest resurgence.

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