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Integrated disease and insect pest management for enhancing production of pulse crops

O. P. Sharma*, N. R. Patange[1], V. Rachappa[2] and S. Venilla

ICAR-National Research Centre for Integrated Pest Management, LBS Building, IARI, New Delhi 110 012; [1]National Agricultural Research Project (VNMKV, Parbhani), Aurangabad 431 001, Maharashtra; [2]Agricultural Research Station (UAS, Raichur), Aland Road, Kalaburgi 585 101, Karnataka

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Abstract

Pulses, largely still being grown on marginal areas of rainfed and due to technological pause, nation is not able to meet current demand of increasing population. With almost no scope to increase the acreage current deficit of pulses can be met partially by avoiding yield losses caused by various diseases pests. Consolidated efforts by ICAR in collaboration with State Agricultural Universities and State Department of Agriculture in farmers participatory mode, has proven that plant protection technologies can help in establishing level of sustainable yield especially among farmers having small holdings. Envisaged technologies have not only contributed in enhancing the yield with lesser use of pesticides but helped in conservation of naturally occurring beneficial both at micro as well as macro niche. Apart from technological aspects present document has also focused on policy issues.

Key words: Pulses, plant protection, integrated pest management, sustainably

Introduction

Pulses are major source of protein for the majority of Indian population and contribute significantly to the nutritional security of the country. Also due to their uses in enriching soil with nitrogen with atmospheric nitrogen, green manure and cover crops in short season cropping windows, breakfast grains and dietary properties, pulses assume significance in our agricultural system. Pulses as a complement to cereals, make one of the best solution to protein-calorie malnutrition apart from its less requirement of water (300 mm). Though India is the largest producer of most of the pulses, its productivity levels are low and therefore, the country imports a huge quantity of pulses to cater domestic demand. In case of lentils, arhar and peas, the productivity is lower than the world average leaving ample scope to enhance it with available technologies. India do not figure in major technological breakthroughs in the world with countries like Canada and others achieving averages of around two tonnes per hectare in pulse productivity, hence concerted efforts are required. With over a dozen pulse crops occupying a large acreage including chickpea, pigeonpea, urdbean, mungbean, lentil, French bean, horse gram, field pea, moth bean, grasspea, grown in different part of the country, pulse production has noticed an upward trend in the recent past and consistently remained over 17 mt. Production data of GOI, indicated that area *vis-a-vis* production have been stagnant over the years with shift in traditional growing areas (www.http://agricoop.nic.in/Agristatistics.aspx). Over the years pulses cultivation in India has been pushed to marginal lands and rainfed areas not providing the crop to express itself fully in terms of yield. Still pulses are cultivated on more than 12 per cent of the Country's total cultivated area and they constitute more than 4% of the output of crop sector in value terms. Pulses being grown in rain fed sufferes crop failure due to wide spread drought in 2009 and resulted in sharp rise in prices of pulses prompting Government of India to review the strategies to increase production of pulse crops to reduce gap between supply and demand. Many of the ideas got implemented like setting up of farmer producer organizations, promotion of farm mechanization for planting and plant protection operations and taking up technology promotional work on a large scale with

*Corresponding author's e-mail: opsharmadelhi@gmail.com
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increased budgetary allocation for pulses. Result is quite evident with the country recording successive years of very high production in 2010-11 and in 2011-12 (Sharma et al. 2012). However same grim situation appeared in the 2014-15 forcing everybody to relook into the strategies and abandoned components. There are basically three constraining factors contributing to low yields of pulses, first being rain-fed and protein rich crops are more susceptible to abiotic and biotic stresses; second due to technological pause, research has not been able to increase current harvest index, develop plant types amendable to mechanization and varieties tolerant to insect pests and thirdly, inadequate marketing infrastructure and unpredictable trade policies.

Current scenario

Pulses are grown in 22.37 m ha area in India. Major areas under pulses are in the states of Madhya Pradesh (20.3%), Maharashtra (13.8%), Rajasthan (16.4), Uttar Pradesh (9.5%), Karnataka (9.3%), Andhra Pradesh (7.9%), Chhattisgarh (3.8%), Bihar (2.6%) and Tamil Nadu (2.9%). Share of chickpea, pigeonpea, mungbean and urdbean to total production has been about 39, 21, 11 and 10%, respectively. Lentil and field pea accounted for 7 and 5% share of total production. The yield levels of pulses have remained low and stagnant (http://agricoop.nic.in/Agristatistics.aspx).

The pulse requirements of the country by 2030 and 2050 are estimated at 22.5, 32.0 and 39.0 million tonnes, respectively. This requires an annual growth rate of over 2%, productivity enhancement of 80 kg/ha every five years, i.e., the level of 950 kg/ha by 2025 and 1,335 kg/ha by 2050. The yield gap in most pulses is attributed to their cultivation in poor and marginal lands with minimum inputs, 87% being rainfed. The geographical shift in pulse cultivation from the indo-genetic plains to central and southern India, also brings out the need for micro-irrigation to enhance the pulse cultivation area especially by providing lifesaving irrigation and to prevent terminal drought.In order to understand the constraints in raising production of pulses in the country the relative profitability and risk involved in pulses cultivation and competing crops needs assessment. The main competition for pulses in India is from cereals both where they gained area and lost area. Gram lost area to wheat in north western plains whereas it gained area from *rabi* sorghum in Andhra Pradesh and Karnataka, from barley in Madhya Pradesh and from linseed and wheat in Maharashtra. In Rajasthan area under gram shifted towards rapeseed mustard. Lentil has been competed out in West Bengal, Haryana and Punjab by wheat but it gained area in Uttar Pradesh, from barley in Madhya Pradesh and from gram in Bihar. Because of long duration of earlier varieties of arhar (Bahar) this crop faced competition from shorter duration crops. In Uttar Pradesh and Madhya Pradesh paddy is found to have replaced it while in West Bengal groundnut gained area from this crop. Arhar gained area from coarse cereals and millets in Maharashtra, Andhra Pradesh and Gujarat. In Karnataka cotton has been driven out by arhar. Large scale replacement of mash took place in favour of *Sesamum* in West Bengal, and in favour of maize in Bihar and Himachal Pradesh. In Andhra Pradesh, Maharashtra and Karnataka mash got area from ragi, sorghum and kulthi. Moong lost major area to soyabeen in Madhya Pradesh but gained area from kulthi in Karnataka, bajra in Andhra Pradesh, jowar in Rajasthan and ragi in Bihar. Gram lost area in Haryana, Uttar Pradesh and Punjab to wheat and in Rajasthan to rapeseed mustard.

Major constraints and scope to increase production

Climatic factors

By and large pulses are mainly grown under rainfed conditions except in few districts of Karnataka, Uttar Pradesh, Madhya Pradesh, Rajasthan Bihar and in certain part of Telangana. As a consequence area under pulses and their productivity are dependent on vageries of monsoon. At one hand, rainfall intensity and distribution leads to vulnerability of *kharif* pulses, water stagnation leading to death and *Phytopthora* diseases in field having heavy soil; and that of *rabi* pulses to water stress at the time of crop maturity making them prone to dry root rot disease. Occurrence of mid-season cold waves often results in flower drops and terminal heat during winter season results in forced maturity (Sharma et al. 2012; Reddy et al. 2015).

Soil

Pulses are very sensitive to acidic, saline and alkaline soil conditions. North-western states have extensive areas with high soil pH whereas eastern and north eastern states have chronically acidic soils compounded with deficiency of micro-nutrients such as zinc, iron, boron and molybdenum and sulphur particularly in Maharashtra and Karnataka. Deep black cotton soils in the states of Madhya Pradesh, Maharashtra, Gujarat, Andhra Pradesh, and Tamil

Nadu get inundated during *kharif* season thereby causing serious damage to pigeonpea, urdbean and mungbeans. On the other hand shallow and coarse textured soils in north and western states have low water rentention and require irrigation for life saving.

Input quality and availability

Extension personnel are not able to recommend pesticides available in market due to the issue of label claim as a result pesticide dealers as ruling whole plant protection affairs and selling pesticides at their will. Effectiveness of quality bio-agents (microbials) in terms of field performance and compatibility with chemical pesticides has been an issue in spite of a well-designed regulatory mechanism put in place e.g., majority of *Trichoderma* formulations are not suited for alkaline as well as fields, where soil temperature goes high. Quality in terms of shelf life of microbials is a major obstacle. Review also indicated that despite several microbials only *Trichoderma* and *Pseudomonas* have been promoted.

Pest management

In absence to access to resistant/tolerant varieties, quality bio-pesticides (*Trichoderma* spp., *Pseudomonas fluorescen* and *Bacillus subtilis*) and fungicides (carbadenzim or thiram) for seed treatment, seed as well as soil borne diseases dominated by *Fusarium* and collar rot alone causes 10% seedling mortality in pigeonpea, chickpea and lentil (Sharma et al. 2015). Once the crop reaches to vegetative stage coupled with conducive climate they often face mortality due to vascular diseases caused by various pathotypes as well as foliar diseases. Very often management strategies have never proved economical. *Fusarium* wilt with many patho-type are wide spread in chickpea (4 Nos.), pigeonpea and lentil growing regions in different agroecological zones. Pigeonpea sterility mosaic which alone causes 50% yield losses in local cultivars is also on increase in rainfed areas. Despite having resistant/tolerant varieties urd and mungbean crops are often damaged by yellow mosaic virus (MYMV: Geminiviridae) and powdery mildew (*Erysiphe* spp.) because of non-replacement of traditional varieties. In addition to prevailing diseases, minor diseases have also started assuming potential threat in view of after effect of climate change (Srinivasan and Sridhar 2008; Subharani and Singh 2007).

As a management tactic, over-reliance on pesticides has impaired the natural crop ecosystem balance by disrupting parasitoid and predator populations, thereby causing outbreaks of secondary pests as now can be seen in pulses. It also contributes to a vicious cycle of resistance in pests, leading to further investment in pesticide development but little change in crop losses to pests, which are estimated today at 30 to 40 per cent, similar to those of 50 years ago. As a result, induced pest outbreaks, caused by inappropriate pesticide use, have increased. Excessive use of pesticide also exposes farmers to serious health risks and has negative consequences for the environment, and sometimes for crop yields. Although pulse crops are prone to as many as 200 pests (Lateef and Reed 1990; Shanower et al. 1999) and seed borne diseases, pod-borer (*Helicoverpa armigera*) in chickpea and pigeonpea has been a major cause of concern as it has developed resistance againg major insecticides (Kranti et al. 2002). Incidence of pod borer, if not controlled, can cause 70% yield losses alone and discourage farmers to grow pulses in these areas. Of late, spotted pod-borer (*Maruca vitrata*) and pod-fly (*Melanagromy zaobtuse*) has emerged as a potential pests in key pulse growing areas and causing yield losses especially in long duration crop (Gopali et al. 2010, 2013; Sharma et al. 2011). Spotted bollworm is emerging in areas having traditional cultivars (Double moti, Gullyal etc.) especially on getting excessive rainfall, however, pod fly incidence is increasing as a result of cultivation of long duration varieties. Pod fly infestation is hidden and difficult to detect before it damages developing seeds (Sharma et al. 2011). Availability of new pesticides (Ganiger 2000; Sharma et al. 2012) no doubt has helped in management of lepidopteran pests more effectively but replacing of generic contact pesticides has resulted in upsurge of sucking insects such as jassids, stem borer as well as pod bugs, which often sucks away saps from developing grains rendering them to shriveled condition. In addition, heavy damage to pulses grain is caused by pests during storage, which often comes from field.

IPM Strategies to enhance productivity of pulses

Over the past 50 years, integrated pest management (IPM) has become and remains the world's leading holistic strategy for plant protection irrespective of crop. From its first appearance in the 1960s, IPM has been based on ecology, the concept of ecosystems and the goal of sustaining ecosystem functions. Keeping its approach efficient pulse productivity in general in any agroecological zone can be enhanced by reducing losses caused by IPM strategies, which have been proven with success in different pulse growing zones (Nagmani et al. 2013; Sharma et al. 2015; Singh et al. 2014; Vinayak et al. 2016). Major strategies are described as below:

Sowing stage

In absence of complete seed replacement, farmers still continues to grow local home saved seeds of varieties, which are susceptible to seed rot and seedling diseases (Chickpea : Wilt (*Fusarium* spps.), Collar rot (*Sclerotium rolfsii*) and dry root rot (*Rhizoctonia battaticola*) – 10-20%; Pigeonpea : Wilt (*Fusarium* sp.) and *Phytopthora drechsleri* – 5%; Mung & Urd : Wilt -5%, Powdery mildew (*Erysiphe polygoni*) – 5-10%; *Macrophomina* blight – 5%), hence replacement with improved varieties can take care of above said issues.

- Replace the local seeds being used by resource poor farmers with disease tolerant varieties, which will take care of seedling diseases caused by *Fusarium*, *Sclerotium* and *Phytopthora* and help in maintaining recommended plant population. In case of chickpea seed treatment can help in limiting spread of seedling diseases (Singh et al. 2013).
- Treat the seeds with local strains of bio-fertilizers (Rhizobium, Phosphate and zinc solubilizing bacteria) and bio-pesticides (*Trichoderma viridae, T. harzianum, T. konigii, T. longibrachiatum, Pseudomonas fluorescens* and *Bacillus subtilis*) will not only provide protection to seedlings but will also serve as PGPR. Across the crop seed treatment with bio-pesticide has proved to reduce seedling mortality by 5% apart from protection from other diseases emerging as a result of increase in soil temperature at terminal stage.
- At many places in eastern India termites and cutworms are major problems causing seedling mortality, hence in such situation recommended dose of dust or wettable formulations of appropriate insecticides should be invariably used.
- Intercrop with trap crops (Coriander and linseeds) provides source of food to beneficial insects in the form of pollen as well as aphids as their food. Lady bird beetle, hoverfly, along with *Campolitis* helps in maintaining pest-defender ratio in chickpea.

Vegetative stage

Large scale mono-cropping need to be monitored on regular basis to curtail pest population at initial stage only and prevent epidemic situation. If pod borer (*Helicoverpa armigera*) are not managed in time, can cause losses to the tune of 70%. It is also important to document the losses caused by emerging pests such as spotted bollworm (*Maruca vitrata* :10-20%), defoliater (*Spodoptera exigua*: 2-5%), podfly (*Melanagromyza obtuse* : 10%), Pod bug (*Clavigrella* spp : 2%), *Macrophomina* blight (emerging) and stem fly of mungbean (*Ophiomyia phaseoli* : 2-5%). Although populations of potential pests are present in every crop field, every day, regular practices such as crop monitoring and spot control measures, usually keep them in check. In fact, the total eradication of an insect pest would reduce the food supply of the pest's natural enemies, undermining a key element in system resilience. The aim, therefore, should be to manage insect pest populations to the point where natural predation operates in a balanced way and crop losses to pests are kept to an acceptable minimum.

- The ability to systematically and efficiently detect and identify insect populations is key to improved integrated pest management (IPM), which relies on the accuracy of pest population monitoring techniques, hence fix up pest monitoring tools such as Pheromone (@ 3/ha) for pod borer and defoliaters and light traps for timing of pest management strategies. Install dead bird perches @ 20/ha to help perching of predatory birds such as Drongo. Our experience says that chickpea crop interspersed with sorghum as well as sunflower serves as live bird perches.
- In case of pests crossing ETL, use appropriate pesticides having label claim. Begin spray with pesticides having green molecules (such as neem oil, emamectin benzoate, chlorantraniliprole) to conserve and enhance beneficial populations (Bhede et al. 2015). Timely use of ovicide followed by anti-feedant and new molecules can reduce losses to the tune of 50%.

Harvesting stage

As per reports, 16% of produce is lost during storage, which can be avoided by preventing infestation coming from fields along with grains. Therefore, harvested grains need to be dried on cemented floor to prevent excessive moisture in the grain before storage to prevent bruchids (*Callosobruchus* spp.) damage.

Technological constraint

There are, however, a few technological issues of general importance which need to be addressed on priorities (as given below) to reduce dependence on import.

1. Development of early maturing pigeonpea varieties so that productivity per unit time could be enhanced and they may fit well in pigeonpea-wheat cropping sequence in the north and could be grown as sole crop in peninsular India during winter season. Development of chickpea varieties tolerant to terminal heat stress for north India and also breeding of chickpea, fieldpea and lentil for tolerance to streses caused due to cold or frost.

2. Pulses are grown under varied agro-climatic conditions (soil types, rainfall and thermal regime) in the country. This calls for region-specific production technology including crop varieties with traits relevant to prevailing biotic and abiotic stresses. Even bio-fertilizers and pesticides used should be based on strains isolated from regions with similar agro-climatic conditions for them to be effective. Our research and development programme in pulses need to address this issue adequately.

3. Production technology for a pulse crop has to be re-oriented to suit soil type/region specific. So is true for tillage and seeding device/gadgets, as a result, farmers are left with no option but to grow *kharif* pulses on flat beds following conventional practices.

4. *Vigna* group of pulses (mungbean, urdbean, mothbean, cowpea and horse gram) are vulnerable to yellow mosaic virus disease and powdery mildew. Though we are able to incorporate resistance against yellow mosaic virus in mungbean, sources of resistance against major diseases are not available in the germplasm. Therefore, search for resistance genes among related and distantly related species must be intensified. Biotechnological approach such as marker assisted breeding should be exploited to develop varieties of these pulses resistant to these two diseases.

5. *Fusarium* wilt in chickpea, lentil and pigeonpea is a devastating disease that drastically reduces plant population. Both conventional and biotechnological tools should be applied for breeding wilt resistant varieties of these crops.

6. Though ICAR has initiated a network programme aimed at the development of transgenics imparting traits such as pest resistance to borers and disease tolerance to abiotic stresses the country is lagging behind in the quest. Transgenic/genetically modified cultivars developed with state of the art biotechnology are now commonly used in some of the pulse growing countries. India should advocate their release.

7. There are heavy post-harvest losses (16%) in pulses, more so during storage. Therefore, development of eco-friendly and affordable grain storage technology for different regions is urgently required.

Strategies for increasing pulse production

ICAR-IIPR, has estimated that by 2024-25, for the projected population of 1.55 billion, the total requirement would be 25.39 mt. Behavioral estimates of demand in relation to elasticities of demand and per capita income growth in real terms may give higher estimates, but even the lower figures require that production would have to be nearly doubled from the 2007-08 levels. Even though the option for importing pulses remains, considering very small global marketable surplus it would be in strategic interests of the country to develop additional sources of pulses supply from within the country or through contracts abroad. It would be worthwhile to diversify the sources of production for imports. If it is found feasible, some policy would need to be evolved for supporting committed pulses production in Latin America and Africa for which present Govt. has already initiated action.

The barren area left after *kharif* rice is estimated to be around 11.65 m ha. The area is primarily rainfed and exists in the states of Bihar, Madhya Pradesh, Chhattisgarh, Orissa, eastern Uttar Pradesh, West Bengal and Jharkhand. About 25% of this area has potential for supporting a *rabi* pulse crop after rice depending on soil type moisture and depth. Assuming an average productivity of 600 kg/ha, the area can produce 1.8 to 2.4 mt of pulses. Farmers need to be encouraged through various incentives and region-specific extension strategy for cultivation of pulses in the identified districts. About 16.5 lakh ha area vacated by wheat, peas, potato, sugarcane and lentil can be utilised for raising 60-65 day summer mungbean crop in Uttar Pradesh, Punjab, Haryana, Bihar, Gujarat and West Bengal where adequate irrigation facilities exist.

Wide spread deficiency of zinc and sulphur in major pulse growing states and boron deficiency in acid soils of eastern and north eastern states has necessitated use of sulphur containing fertilizers and zinc sulphate as a source of zinc. Sulphur application @ 20-40 kg/ha (through gypsum, SSP) or elemental sulphur at sowing and zinc sulphate @25-50 kg/ha once in two years effectively address the problem and tend to maximize crop productivity. Our field experimentation at Gulbarga, Karnataka indicated that it leads to increase in flowering and improves size of the grain.

Of late, mixture of micro nutrients developed by TNAU, Coimbatore (Pulse Magic) as well as by ARS, Gulbarga (Pulse Wonder) has proven very effective in enhancing yields in mung as well as urdbean. Spray of 2% urea on pigeonpea at flowering stage has also proved effective in enhancing yield.

Ridge-planting of *kharif* pulses in black soil region (Madhya Pradesh, Chhattisgarh, Gujarat, Andhra Pradesh and Tamil Nadu) improves crop productivity and sustainability of production as it ensure drainage of the root zone during intense rains and facilitates in- situ conservation of rain-water to be used by rabi crops.

Development of short duration pigeonpea varieties which fit into a cropping sequence such as pigeonpea-wheat/gram will substantially contribute to area expansion under pulses. Short duration pigeonpea are highly susceptible to insect pests, hence this aspect need attention to make adoptable.Development of cold/heat tolerant varieties of lentil and chickpea has become necessary in view of climate change.

Due to farm labour shortage, weed infestation of pulses has been observed to cause heavy yield losses in *kharif* and *rabi* pluses. Problem of weed has increased in the areas receiving unprecedented continuous rainfall, hence use of recommended herbicides particularly during *kharif* needs to be promoted as sometimes frequent rains and too wet soil conditions do not allow mechanical/manual weeding.

Insect pests directly damage crops causing significant losses, and pest control has always been considered the most difficult challenge to overcome. The main reason is that the dynamics of the pest population density in the field can not be accurately monitored, hence as on now we need to rely on networking of collaborators to have real time information on pest built up. It is important that region specific advisories are issued using state of art technologies based on ICT promoted by Govt. of India (Singh et al. 2016; Sharma et al. 2011), for timely guiding pulse growers on pest control. This calls for an effective pest surveillance mechanism to be put in place at district level. The key features of area-wise Integrated Pest Management to be adopted are listed below:

i. Demonstration of IPM module/strategies in farmers' participatory mode in cluster mode.

ii. Pests and diseases will continue to be a major challenge to the agricultural industry, hence regionalization as a common strategy may be used to address pests and diseases that threaten agricultural productivity especially in pulse bowl such as Maharashtra, Karnataka and Rajasthan. It will help separates the disease-free and affected areas reducing production cost. Pest outbreaks present challenges that require new regulatory and policy approaches.

iii. Pest and disease damage can be substantially reduced when farmers grew different varieties with diverse resistances together. Growing a combination of varieties together also makes farming systems more resilient to new pests and diseases.

iv. Capacity building of farmers, Subject Matter Specialist, and Extension functionaries to update them with recent advances in the field of plant protection can help to mitigate pest losses.

v. We need to determine how much production is at risk, in order to establish the appropriate scale of pest control campaigns or activities. Infestation of more than 10 per cent of a crop area need to be considered as an outbreak, and required a rapid policy response. However, risks from pests are often over-estimated, and crops can to some extent compensate physiologically for pest damage. The response should not be disproportionate.

vi. Routine roving as well as fixed plot surveys on weekly basis during peak crop season should be carried out so as to provide real time data base based pest advisories for use by Reporting and Alert System established at DAC&FW (Sharma et al., 2011, 2012 and 2015) through m-kisan.

vii. Pests and diseases are a natural part of any ecosystem, hence what we should fear is the outbreaks or epidemics that can cause high yield losses. In this connection periodic and timely release of pest advisories using m-Kisan and Dordarshan by the state functionaries can be of great help.

viii. Ensuring that the advices are complied with provisioning of the needed biological or chemical pesticides to offbeat the epidemic situations caused by pests of national importance can lead to success.

ix. Irrespective of crop there is a need to give preference to less hazardous pesticides in registration processes. Govt. policy should ensure that the traders/farmers takes an ecologically informed decision as to which pesticides may be sold and used, by whom and in what situations. Eventually, pesticide-use fees or pesticide taxes, which were pioneered in India in 1994, may be used to finance the development of alternative pest management practices and subsidize their adoption.

x. Sustaining IPM strategies will require effective advisory services, linked to research that respond to farmers' needs, support to the provision of IPM inputs, and effective regulatory control of chemical pesticide their distribution and sale.

By the end of 2020-25 reduction in existing level of post-harvest losses by creating infrastructure support for processing and storage it can be reduced to the tune of 30% amounting to 1.5 mt. So far, the market potential is huge, hence leaves no room either to attend the import requirements, which return goods with residue, or the pressure of the society for a more sustainable agriculture or due to the plague resistance, integrated management will be one of the pillars of nutritional security.

Declaration

The authors declare no conflict of interest.

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