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KN Gupta
PC Unit, All India Coordinated Research Project on Sesame and Niger; JNKVV Campus, Jabalpur, Madhya Pradesh, India

KR Naik
PC Unit, All India Coordinated Research Project on Sesame and Niger; JNKVV Campus, Jabalpur, Madhya Pradesh, India

Rajni Bisen
PC Unit, All India Coordinated Research Project on Sesame and Niger; JNKVV Campus, Jabalpur, Madhya Pradesh, India

Correspondence
KN Gupta
PC Unit, All India Coordinated Research Project on Sesame and Niger; JNKVV Campus, Jabalpur, Madhya Pradesh, India

Status of sesame diseases and their integrated management using indigenous practices

KN Gupta, KR Naik and Rajni Bisen

Abstract
Sesame phyllody is the most destructive disease in India. Among the fungal diseases, *Alternaria* leaf blights, *Phytophthora* leaf spot, *Cercospora* leaf spot *Macrophomina* root /stem rot, Powdery Mildew, Bacterial leaf spot and Bacterial blight are important diseases of sesame. The incidence of important diseases varies from state to state based on agro climatic situations. Seed treatment with Thiram (0.2%) +Carbendazim 50WP (0.1%) and foliar spray should be done with Wettable sulphur (0.2%) was most effective to minimize the incidence of powdery mildew. For bacterial diseases Streptocycline (250-300ppm) may be used for seed treatment. Seed treatment with Thiram (0.2%) + Carbendazim 50WP (0.1%) and two foliar sprays of (Mancozeb 2%+ Carbindazim1%) was effective in reducing the *Alternaria* and *Cercospora* disease and highest yield. Seed treatment with Imidacloprid (@ 5 ml/kg seed) followed by foliar spray of Thiomethaxam @ 0.2 g/l was found effective in reducing the vector population and phyllody incidence. Seed treatment with *Trichoderma viride* (5g/kg seed and soil application of *T. viride* @ 2.5 kg/ha was found effective and economical for the management of *Macrophomina* root /stem rot of sesame.

Keywords: Sesame, diseases and management

1. Introduction

Sesame (*Sesamum indicum* L.) is one of the oldest oil seed crop and is under cultivation from ancient times (Weiss, 1971) [78]. India contributes the highest sesame acreage of above 17.73 lakh hectare and production 8 lakh tones and productivity of 445kg/hectare. The low productivity is attributed to poor crop management and exposure of the crop to a number of biotic and a biotic stresses. It is also known as generally, til, popularly as “Queen of Oilseeds” due to its stabilized keeping quality contributed by high degree of resistance to oxidation (Bedigian and Harlan, 1986) [18]. Sesame is believed to have been originated in India, where maximum variability in genetic resources is present (Bhat *et al*., 1999) [19]. India is a major exporters to number of countries and has earned the foreign exchange of Rs 2800 crore. The uniform, white and bold seed, free from insect pest and pesticide residue, with low free fatty acid (>2%), low oxalic acid (<1%) and high lignin content (>830 mg/100 g seed), is preferred for export. At present chemical fungicides are the first choice for the farmers to combat diseases because of their easy adaptability and immediate therapy. Due to health risk and pollution hazards by use of chemical fungicides in plant disease control, it is considered appropriate to minimize their use. Since sesame seed and oil are in high demand for export due to their high unsaturated fat and methionine content, focus has been shifted out safer alternatives to chemical fungicides in recent years. Biological control had attained importance in modern agriculture for disease control. Since the efficacy of bio-control agents in disease abatement has been inconsistent due to their inability to maintain a critical threshold population necessary for sustained bio-control activity, bio-control with antagonistic microorganism alone could not be a complete replacement for management strategies currently employed. The activities and population of introduced antagonist generally decline with time after their application and thus making the beneficial response of short duration. To enhance and extend the desired response, the addition of specific substrates which are utilized selectively by the introduced microbe employed as biocontrol agent (Paulitz, 2000) [53]. Therefore Integrated Disease Management (IDM) that incorporates the biocontrol agents, botanicals and organic amendments would reduce the amount of fungicides used per season in addition to combat diseases in an economically viable and ecologically safe proportion.

The area and production of sesame crop is declining in the traditional areas. Despite the potential for increasing the production and productivity of sesame, there are a number of challenges inhibiting sesame production and productivity. Among the many production constraints, the most important include lack of improved cultivars and a poor seed supply system. In addition, there are severe biotic stresses, such as root rot /stem rot (*Macrophomina phaseolina)* (Tassi) Goid, (Bacterial blight (*Xanthomonas campestris* pv. Sesame), Phyllody (a Mycoplasma –like organism), Powdery mildew (*Oidium erysiphoides),* Alternaria leaf spot *(Alternaria sesame*) and Cercospora leaf spot (*Cercospora sesame*). Sesame diseases cause damage to seed, seedling, root, stem as well as foliage resulting in significant loss. The use of Eco-friendly pest control method has got tremendous scope since the diseases are controlled without putting any threat to the quality of produce and surrounding ecosystem. Major diseases, their characteristic symptoms and control measures recommended for their eco-friendly management furnished briefly are given below.

2. Major diseases of sesame

2.1 Phyllody (*Phytoplasma*): It is a serious and wide spread disease of sesame and caused by a pleomorphic mycoplasma–like organism (MLOs) which is now called as phytoplasma (Choopanya, 1973) [22]. The phyllody is transmitted by the insect vector *Orosisius albicinctus*. The disease has been noticed recorded in India, Iran, Israel, Burma, Sudan, Nigeria, Tanzania, Pakistan, Ethopia, Thailand, Turkey, Uganda, and Mexico (Akhtar *et al*., 2008) [4]. The infected plant is characterized by transformation of all floral parts in to green leafy structures followed by abundant vein clearing in different flower parts. In severe infection, the entire inflorescence is replaced by short twisted leaves closely arranged on a stem with short internodes and abundant abnormal branches bend down. Finally, plants look like witches broom. In some tracts phyllody cause crop losses as high as 99 per cent in yield. The losses as high as 90% has been reported by Gopal *et al*., 2005 [31]. The affected plants become stunted and the floral parts being modified in to leafy structures bearing no fruits and seeds causing yield loss up to 33.9% (Abraham *et al*., 1977) [3]. Host range studies were also conducted for the Jassids (Sundararaju and Jayaraj, 1977) [72]. It is reported that sesame phylllody diseases prevalent throughout the year. Setkaya, 1999 studied that sesame phyllody to test plant by grafting, dodder and Insect. In addition to common cultural, mechanical and biological practices, Intercropping of Sesame+redgram (6:1) and spraying of neem oil @50ml/l for vector (leaf hopper) control is helpful in managing the phyllody. The tolerant varieties are TKG 21, RT-125 and RT-103. Intercropping of Sesame+Pigeonpea (1:1) is helpful for the management of phyllody.

2.2 Stem and Root rot: Stem and Root rot are caused by *Macrophomina phaseolina* (Tassi) Goid (Mihail, 1995) [45]. The symptoms were produced at ground level stem becomes black, which extends upward rupturing the stem and Black dots appear on the infected stem. The roots will become brittle. In disease infected plants, black capsules are seen which open prematurely exposing shriveled seed. The diversity of host species and the geographic range have suggested that *M. phaseolina* is quite hetero-geneous. Its variability has been confirmed by reports demonstrating differences in pathogen city of isolates obtained from both a single plant and a single host species (Babu *et al*., 2010: Jana *et al*., 2005; Saleh *et al*., 2010) [16, 35, 64]. Despite having a wide host range, only one species is recognized within Macrophomina. The disease also cause severe losses right from seedling to maturity of the crop (Khan, 2007) [39]. The tolerant varieties are RT-46, RT0125, MT-75, TKG-22 and Nirmala. Intercropping of Sesame + Mothbean (1:1 or 2:1) is helpful for controlling stem and root rot.

2.3 Cercospora leaf spot: The disease is caused by (*Cercospora sesami* Zimm) and is one of the most economically important diseases of sesame in almost all the production area. The crop is affected by the pathogens at all stages of the growth and causes heavy economic losses. Due to lack of resistant sources the released varieties are highly susceptible to *Cerospora leaf spot*. It appears as small, angular brown leaf spot 5-15 um in diameter on both leaf surfaces. Under favorable conditions, the disease spreads to leaf petiole, stem and capsules producing linear dark coloured lesions. The damage to plant growth and grain yield depend on the severity of infection on the stem and pods and the stage at which the infection takes place. The fungus is seed borne, both internally and externally, but can also survive in the plant debris Thus, primary infection in the field may be from seed and infested plant debris and secondary spread may be through wind borne conidia. Extensive infection of foliage and capsule leads to defoliation and damage of sesame capsule and yield losses may range from 22 to 53% (Enikuomehin *et al.*, 2002) [28]. Intercropping of Sesame+Pearl millet (3:1) is helpful for controlling *Cercospora* disease.

2.4 Powdery mildew: Powdery mildew caused by *Erysiphae orantii Cast* (Rajpurohit, 1993) [55]. It is the is the most important disease of sesame, occurring widely throughout India and causes substantial qualitative and quantitative loss to the crop. It occurs in epidemic scale under heavy rainfall condition followed by low night temperature and high humidity. It appears at flowering to capsule formation stage as small patches of white powder on upper side and occasionally on lower surface of leaves. Defoliation of severely infected plant occurs before maturity. Powdery mildew causes yield losses ranging from 25 to 50% depending upon the level of incidence an average yield loss of 45% has been reported to be caused by Powdery mildew (Shambharkar *et al*., 1997).

2.5 Phytophthora blight: Phytophthora blight **(***Phytophthora parasitica* var. *sesami***)** produces initial symptoms of water soaked spots on leaves and stem. The spots are brown in the beginning which later turns to black. Disease can attack at all the stages of the crop (Roy *et al*., 2007) [62]. Phytopthora tolerant varieties are MT-75, TKG-22and TKG055. Inter-cropping of sesame + Pearl millet (3:1) also helpful for controlling Phythopthora disease,

2.6 Alternaria leaf spot: The disease caused by (*Alternaria sesami*) is one of the most common and economically important foliar diseases of sesame. The disease reported in different sesame growing parts of the country by many workers (Mehta and Prasad, 1976 and Dolle, 1981). It affects the plants at all stages and symptoms produce are small dark brown water soaked, round to irregular lesions with concentric rings varying from 1-8 mm in diameter (Mohanti and Behera, 1958) [46]. In severe infections several spots involving major portions of leaf blade and later drop off from the plants Alternaria blight affects severely at all stages of the crop growth during kharif seasons. The plants were observed to be most susceptible at 8-10 week's age (Ojambo *et al*., 1999). Dark brown spots are developed on cotyledons, water soaked circular or irregular brown spots on leaves, and brown stripes are formed on stem by the fungus. Resistant varieties are the best option for managing Alternaria blight and some resistant sources have also been reported by Natrajan and Shanmugam, 1983 [49] and Rajpurohit *et al*., 2008. Intercropping of sesame + pearl millet (3:1) is helpful for controlling Alternaria disease.

2.7 Bacterial Blight: On leaves purple brown specks which develop in to large spots and defoliate symptoms produce by Bacterial blight (*Xanthomonas Compestris* pv. *sesami*) (Cook, 1981). Bacterial leaf spot of sesame which was affecting the plant at all age and causing the seed infection is one of the major causes for the dispersal of diseases and the resulting plants have poor growth (Kottle, 1985) [41].

2.8 Bacterial leaf spot: Light brown angular spot with dark purple margin appears in the leaf veins are the symptoms produced by Bacterial leaf spot (*Pseudomonas syringe* pv *sesame* (Cook 1981) [24]. Pseudomonas and other Gram–ve bacterial genera infected plants through natural opening such as tomato and wounds. Multiplying in the intercellular space out side of the plant cell wall and produce virulence factors which contributed to the formation of the symptoms.

3. Plant health management using indigenous practices: Integrated disease management (IDM) system were evolved and used by the farmers from ancient time before the emergence of crop protection. In recent years application of chemicals in plant protection has posed several problems of development of resistance in pathogens and pesticide residues in seed produced. Hence, we have to go for eco-friendly disease management which involves the best mix of effective and reliable control measures particularly the field techniques to minimize the dependence on the pesticides. Thus IDM is a powerful concept and is both economically as well as easily operational tool for maintaining plant health and ecology. The IDM is structured to use an assortment of cultural, agronomical, resistant varieties and use of bio-pesticide and bio-control agents and final use chemical control. Due to health risk and pollution hazards by use of chemical fungicides in plant disease control, it is considered appropriate to minimize their use. Biological control had attained importance in modern agriculture to curtail the hazards of intensive use of chemicals for disease control. Since the efficacy of bio-control agents in disease abatement has been inconsistent due to their inability to maintain a critical threshold population necessary for sustained bio-control activity, bio control with antagonistic microorganisms alone could not be a complete replacement for management strategies. The activities and population of introduced antagonism generally decline with time after their application and thus making the beneficial response of short duration. To enhance and extend the desired responses, the environment needs to be altered to selectively favors the activities of the introduced bio-control agent and this can be overcome by the addition of specific substrates which are utilized selectively by the introduced microbe employed as bio-control agent (Paulitz, 2000) [53]. Therefore, integrated disease management (IDM) that incorporates the bio-control agents, botanicals and organic amendments would reduce the amount of fungicide used per season in addition to combat diseases in an economically viable and ecological safe proportion. Soil amendments are known to improve the nutrient status and tilth of the soil in addition to increase the microbial activity and to suppress pathogens, bio-control agents can grow, proliferate, colonize and protect the newly formed plant parts to which they are not applied; phyto-pesticide materials range from whole fresh plants to bioactive phyto-chemicals or their formulations are known to inhibit pathogens and hence they are considered as attractive supplements to the conventional methods for plant disease management. Effect of IDM modules with chemicals, botanicals, organic amendments and bio-control agents on disease incidence and yield of sesame in comparison with farmer practices. (Jeyalakshmi *et al*. 2013) [36].

3.1 Resistant Varieties

Development of a resistant variety requires the knowledge of genetics and inheritance of the disease resistance. However, there are limited studies reporting the inheritance of phyllody resistance in sesame. Sing *et al*., 2007 reported that a single recessive gene governs resistance in cultivated varieties (KMR 14 and Pragati) whereas, wild species posses a single dominant gene conferring resistance against phytoplasma. Parani *et al*., 1996 [52] suspected that resistance in S*esamum alatum* Thonn may be control by single recessive gene, but later it was concluded that resistance to phyllody in *Sesamum altum* Thonn was only due to insect resistance. In most of the cultivated genotype were found to be highly susceptible to Alternaria leaf blight expect RT-273 and some promising crosses were advanced to F7 (Naik *et al*., 2003) [48] and wild species like *S. radiatum, S. prostatum, S. lacinietum, S. mulayanum and S. occidentale* var. malabaricum were found to be resistant. Breeding for disease resistance through conventional approach is still in infancy (Kariyallappa *et al*., 2003), Mainly because of very few resistant genotypes identified in *Sesamum indicum* types. Field screening of germplasm, either indigenous or exotic, by several workers has resulted in availability of very few resistance genotypes (Naik *et al*.. 2003) [48]. As varietal replacement is able to provide a spatial and temporal discontinuity against the pathogen, therefore, use of resistant varieties has been the main approach is disease control. The use of resistant varieties is the cheapest, easiest, safest and most effective means of controlling plant diseases in crops for which some varieties are available. Following are tolerant varieties for major disease of sesame.

Table 1: Tolerant varieties for major diseases of sesame.

Variety	Phyto	MSR	BLS	BLB	Alt	Cer	Pm	Phyll	LC
JT-21	+			+		+			
TKG21								+	
TKG-22	+								
TKG-55	+	+							
JTS-8			+		+				
RT-48		+							
RT 46	+								
RT-54		+			+				
RT-103		+	+					+	
RT-125	+	+	+					+	
RT-127		+		+		+	+	+	
Sekhar								+	+
Gautam					+				
Usha					+				
TSS-6					+			+	
M-75							+		
Sweta									
Nirmala	+								

Pb: Phytophthora blight; MSR: Macrophomina stem/root rot; Bis: Bacterial leaf spot Blb-Bacterial leaf blight; CLS: Cerspora leaf spot; Pm: Powdery mildew
Phyll: Phyllody; Lc: Leaf curl ; Als: Alternaria leaf spot
(Anonymous, 2003)

3.2 Cultural control: Soil amendment with farm yard manures @ 5 t/acre is helpful in reducing the incidence of the disease. Avoidance of planting overlapping crops in adjacent. Crop rotations Viz. Sesame Maize- Cabbage, Okra-Sesame-Maize, Miaze-Sesame-Maize are reported to be effective in reducing disease incidence. Crop rotation with non host crops. Particularly with rice, not only help reducing the disease incidents but also in proving good drainage. Destruction of crop debris, removal of alternate weed host, providing irrigation at critical stages of the crop, an avoiding water logging and water stress during lowering stage help controlling pest and diseases. Avoidance of chemical spray when 1-2 larval parasitoids are observed help to enhance parasitic activity.

Table 2: Cultural control for the management of sesame diseases.

S. No	Practice	Disease management	Reference
1	Pathogen free sites	All diseases	
2	Sanitation	All diseases	
3	Deep ploughing in summer	*Sclerotium rolfsi,* diseases caused by *phytopthora, Rhizoctonia and Fusarium*	Annonymous, 2000; Backer and Cook 1974
4	Good drainage	Phytophthora blight, Fusarium root rot, vascular wilt, Macrophomina root rot/stem rot	Anonymous, 1993 Jain and Kulkarni, 1965
5	Soil Solarization	*Macrophomina* stem/root rot, phytophthora blight	Dinakaran *et al.,* 2001
6	Manipulation in planting		
	A). shallow planting (1’)	Rhizoctnia root rot *Macrophomina* stem and root rot	Leach and Garber, 1970
	B) Plant spacing	30x10 cm (3 lakh plants/ha) reduced Macrophomina stem/root rot and phyllody	Anonymous, 1993
	c) Early planting (immediately after onset of monsoon)	*Cercospora leaf* spot, *Alternaria leaf* spot and bacterial blght	Anonymous, 1989
	d) Late planting (about 3 weeks after onset of monsoon)	Macrophomina stem and root rot. Rhizoctonia root rot and phytophthora blight phyllody	Anonymous, 1992 Rathaiah, 1985 Mathur and Verma, 1972
7.	**Soil amendment**		
	Mustard cake	*Rhizoctonia and Fusarium* diseases	Gemavat and Verma, 1971
	Sesame cake (2000) kg/ha Neem cake (250 kg/ha)	Macrophomina stem and root rot	Mohanti and Mukharjee, 1982
	a. Urea	*Rhizoctonia* diseases	Sezin and Onan, 1987
	Urea (20 kg N/ha + FYM (20 kg N/ha)	do	Sing *et al*., 1990
	NPK (50,25,25)	do	
	Wheat or soybean straw	do	
	Nitrogen @45 kg/ha	Bacterial blight	Habish and Hammad, 1970
8	Crop rotation	*Phytophthora blight, Fusarium wilt and Root rot Macrophomina root and stem rot, Corynespora* blight	Anonymous, 1992 Leach and Garber, 1970
9	Intercropping system		
	a)Sesame + Perl millet(4:1)	*Phytophthora blight and Cercospora leaf spot*	Anonymous, 1997
	b) Sesame + Mothbean (1:1 or 2:1)	*Macrophomina stem and root rot*	Anonymous, 1997
	c)Sesame +Pigeonpea (1:1)	*Phyllody*	Anonymous, 1997
	d)Sesame +sunflower (6:1)	*Macrophomina stem and root rot*	Anonymous, 1997
10	Mixed crop with Urd moong bean, Cowpea and Mothbean	*Fusarium and Rhizoctonia root rot*	Verma and Daftari 1975; Anonymous 1997
11	Irrigation every 2 weeks (Whenever necessary)	*Macrophomina stem/root rot*	Jain and Kulkarni, 1965;
12	Removal and destruction of disease plant	*Wilt root disease and phyllody*	
13	Destruction of collateral host	*Bacterial blight*	Anonymous, 2003

3.3 Physical method: Hot water treatment at 52ºC for 10 minute for effective control of bacterial pathogens.

3.4 Biological control: Species of *Pseudomonas, Bacillus* and *Streptomyces*, which are most active at 25ºC – 27ºC at field capacity moisture level could be suppressive of *Phytophthora* species in soil. *Trichoderma* species, which are common soil fungi, are also antagonistic to *Phytophthora* species. The mechanism involve in suppressing by antagonist may be hydrolysis, abortion of sporangia or place, substance competition. Application of PSB along with neem cake or 50% NPK + FYM or NPK + PSB reduced Phytophthora Blight (Verma and Bajpai, 2001). Wilt and root rot diseases were suppressed when the three isolates of *Bacillus subtalis* applied in artificially infested soil (Gabr *et al*., 1998). Seed treatment with *Trichoderma harzianum* and *T. viride* (0.4%) reduced the incidence of Macrophomina stem/ root rot and the treatment of *Pseudomonas fluorescens* (0.4%) reduce the incidence of *Cercospora leaf spot*. *Trichoderma viride* was found to be equal to fungicides to reduce Macrophomina stem/root rot. Seed treatment of *Trichoderma viride* or T. *Harzianum* (0.4%) (Anonymous, 2000) and Soil treatment with *Trichoderma viride* or T. *Harzianum (2.5kg/ha)* very effective for management of soil borne pathogens (Anonymous 2013, Anonymous, 2015).

3.5 Seed treatment with fungicides/ antibiotics: For the prevention of seed born diseases, use the seed essentially treated with Thiram (1.5 g) + Bavistin (1.5g). Wherever bacterial leaf spot disease is a problem, soak the seed for 30 minutes in 0.025% solution of Agrimycin prior to seeding. El-Khadem *et al.,* 1991 found that Benlate fungicide was found most effective. Khlifa, 1997 reported also that Rizolex-f or Benlate as seed treatment +Chlorneb as soil treatment were superior for controlling root rot and wilt diseases and increased seed yield of sesame under field conditions. Seed treatment with *Trichoderma viride* @4g/kg of seed *Pseudomonas fluorescens* @ 10g/kg seed or *Bacilus subtillis* @ 10g/kg seed and Neem seed kernel extract (NSKE) 5% (Augstburger *et al*., 2000) help controlling soil borne pathogens.

Table 3: Bio-agents and botanical pesticide managing sesame disease

Practice	Disease managed	Reference
Bio-control agent		
Trichoderma sp.	*Rhizoctonia solani Macrophomina phaseolna*	Pineda *et al*., 1988; Zape *et al*.,2014
Trichoderma viride	*Fusarium oxysporum* f. sp. *Rhizoctonia solani* Phytophthroa blight *Macrophomina* stem/root rot	Chung and Choi, 1990 Jharia and Duhoon, 2000; Rajpurohit, 1999
Trichoderma harzianum	*Phytophthora* blight, *Macrophomina* stem/ root rot	Rajpurohit, 1999
Bacillus subtilis	Macrophomina stem/ root rot	Rajpurohit, 1999; Bhattacharyya *et al.*,2014; Singh and Verma, 2015; Vyas and Patel, 2015; Savaliya *et al.*, 2016
T. harzianum	Sclerotium rolfsii	Gaikwad and Kapgate, 1990
Bio-pesticide		
Neem oil 5% Neem seed karnel extract (3%)	Phyllody	
Neem cake (250 kg/ha)+ *Trichoderma viride (2.5 kg/ha)* *Seed treatment with Trichoderma viridae @5g/kg seed+P. Fluorescens +Soil application of T.Viridae +Soil application of P.fluorescens @2.5kg/ha*	*Macrophomina* stem/ root rot	Rajpurohit 2008; Rajpurohit, 2013 Gupta and Ranganatha, 2014
Foliar spray of neem oil 3% might be due to the presence of sulphur containing compounds viz., nimbidin and *azadirachtin*.	Powdery mildew	Rettinassa babady *et al*., 2000

3.6 Soil/ foliar application of fungicides

Table 4: Need based fungicidal application for the control of sesame diseases

Disease	Chemical	Mode of application	Reference
Root rots; Rhizoctonia root rot, collar rot, Macrophomina stem and root rot	Thiram (0.15%) + Captan (0.15%) (1:1) + Urea (2%)	2-3 time soil drenching along with the plant using sprayer without nozzle from the imitation of disease at 7 days interval	Jharia and Duhoon, 2000
Fusarium root rot, Vascular wilt	Daconil (chlorothalonil)	Soil treatment	Seoud *et al.*, 1982
Phytophthora root rot	Ridomil Mz (0.25%)	Soil treatment	Seoud *et al.*, 1982
Foliar Diseases- Cercospora leaf spot	Topsin-M (0.1%) Mancozeb (0.25%) Difenoconazole (0.1%) Carbindazim 50wp+Mancozeb	3 sprays as and when disease appear at 15 days interval	Anonymous, 1992
Alternaria leaf spot	Carbindazim 50wp (0.1%); Mancozeb (0.25%) Carbindazim 50wp+mancozeb	3 sprays as and when disease appear at 15 days interval --do-- --do--	Abraham *et al*., 1976; Swain *et al*., 1989 Anonymous, 1997;
Corynespora blight	Zineb (0.25%)	---do--	Anonymous 1993
Bacterial leaf spot	Agrimycin 100 (250 ppm) Cupervit 50 (0.5%) or Difolatan 80 (0.16%)	--do-- --do--	Verma and Daftari, 1976; Urdaneta and Mazzani, 1976
Powdery mildew	Sulfex (0.2%) Karathane (0.2%)	2 sprays starting from the imitation of disease at 10 days interval 2 spray at the beginning of flowering and fruiting	Sharan *et al.*,1985; Anonymous, 1992 Castellani and Jama, 1984
Phyllody and leaf curl	A) Phorate 10 g (10 kg/ha) Dimethoate (0.03%) Profenofas/sponosad	Soil application 2-3 foliar sprays	Anonymous, 1992

Integrated disease management plays a vital role in increasing the productivity. Deep ploughing with mould board plough in summer, good drainage, crop rotation to avoid repeated growing of crop in the same field over two years. Manipulation of sowing time, intercropping with cowpea, pigeon pea, per millet, moog bean, urbane, moth bean and sunflower, good crop management to avoid the street conditions, resistant / tolerant varieties, seed treatment with *Trichoderma viride* (0.4%)+ Neem seed kernel extract (3%) and supplementary need based chemical sprays manage the insect pest, diseases and pesticide residue problem to a great extant.

4. Molecular marker based research

DNA markers provide powerful tools for genetic evolution and marker –assisted breeding of crops and especially for cultivar identification. Among the different types of molecular markers, Random amplified polymorphic DNA (RAPD) markers are particularly useful for the assessment of genetic diversity because of their simplicity, speed of application and relatively low cost (Nybom, 2004). RAPD markers have been used extensively in several crops. Abdellatef *et al.,* 2008 used RAPD markers to investigate the genetic diversity of 10 selected sesame germplasm accessions of Sudan. Genomic resources (markers/maps/ genes/alleles) in our crops are scanty and developing these in oilseed crops will be a priority. Cost effective and highly efficient next generation sequencing (NGS) technologies can also be used to accelerate the development of genomics resources in safflower with limited investment. Once the genomics resources are developed, using them in marker-assisted backcross breeding programmes for monogenic traits. Also, these resources would be used to map the quantitative trait loci (QTLs) controlling important traits like biotic and a biotic stress tolerance. Genome-wide association studies (GWAS) based on linkage disequilibrium (LD) provide a promising tool for the detection and fine mapping of quantitative trait loci (QTL) underlying complex agronomic traits. With the availability of a good collection of germplasm lines, would be used more effectively in oilseed crops to establish association of genotypic variability with phenotypic data. These approaches would be tested in oilseed crop improvement programmes especially for traits that are difficult to be addressed through conventional approaches. Considering the successful examples of using molecular breeding tools for improving complex traits such as drought tolerance and yield enhancement in crops such as corn and rice, it is expected that these improvements will be a reality in oilseed crops also.

5. Researchable Issues

Development of varieties with high seed yield, oil content, with resistance to biotic and a biotic stresses. Generation of genetic variability for resistance to biotic and a biotic stresses and quality improvement by transferring alien gene(s) from closely related or unrelated sources through wide hybridization and biotechnological tools. Basic studies like genome analysis and gene tagging to have knowledge on the genetic architecture of the genotypes, for application in the applied breeding. Phytogenetic approach to study the relationship with the wild relatives through molecular cytogenetic and biochemical/molecular markers. Development and identification of genotypes devoid of toxic and anti-nutritional factors would help in using the byproducts like oil cakes. Studies on biochemical and physiological basis of resistance against major insect, pests and diseases. Development of IPM modules for diseases and insect, pests. Survey, identification and evaluation of various biological agents (parasites, predators and insect pathogens/microbes) for their efficacy against major diseases.

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