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A study on the management of biotic and abiotic threats in chilli crop cultivation

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Abstract
Chilli is one among the important commercial spices. It has a significant demand in the market because of its use in day-to-day life. Cultivation of chilli has its own difficulties because of the biotic (insects & diseases) and abiotic (water related problems & nutrient related problems) threats. For managing both the threats, it requires an integrated approach for making it smooth and affordable. Excess irrigation leads to the vigorous growth of weeds and pests. It can be controlled by opting for drip irrigation which can save water up to 62% and inclines the yield up to 43% in chilli. Nutrient deficiency also can be threat to the crop. It has to be maintained by providing the appropriate fertilizers with recommended dosage. Combined application of organic manures (FYM, poultry manure, neem cake) and inorganic manures along with bio fertilisers (Azospirillum, Phosphobacteria) help the growth and yield of the chilli crop by enhancing the nutritive uptake. Biotic threats (insects & diseases) can be maintained by the mixed approach of management practices *viz*., crop rotation, installation of traps (yellow sticky, blue sticky and pheromone), planting the border crops (maize, sorghum), botanicals application (Neem cake, neem oil) and minimal toxic chemicals can effectively control the pest population in chilli. Leaf curl virus is the fatal disease which can only be prevented rather than managed. For rest of the fungal diseases (Anthracnose, Cercospora leaf spot) biocontrol control agents like *Trichoderma* spp. can effectively control the diseases. This review paper is the baseline work of future DST-SEED project at Guntur, Andhra Pradesh India.

Keywords: Chilli, threats, Drip irrigation

Introduction
Chilli which is otherwise called Wonder spice or Universal spice originated from South Central America. Chillies are cultivated in almost every part of the world *viz*., Mexico, Africa, India, Japan, USA etc. Portuguese introduced the chilli to India. India produces 40% of total chilli production in the world. India which is considered "the home of spices" produces chillies practically every season because of the suitable climate conditions, soil properties, irrigation facilities and intensive practices followed by farmers. According to the 2019-2020 estimate, the total area under chilli production in India was 682.58ha and produced an average chilli yield of 2494kg/ha. (National Horticultural Board, 2019-2020). According to FAO 2018 report, 21% of the total produced dry chillies in India were exported to other countries. Majorly chilli producing states in India are Andhra Pradesh, Karnataka, West Bengal, Madhya Pradesh, Maharashtra and Tamil Nadu. Chillies are mainly consumed in the form of chutneys, pickles, curries etc. (Singh, 2020) [76, 77].

Based on the utility, different varieties are cultivated differing in flavour, pungency and colour. Chillies are a good source of nutrients like Vitamin A, Vitamin C, Vitamin B6, Potassium, Iron and Magnesium. Vitamin C was noticeably high in green chillies than in red chillies. (Sparkby, 2006) [81] Small scale farmers consider chilli crops as assuredly beneficial crops. (Patil *et al*., 2014) [59] For the cultivation of chilli, factors required are proper soil conditions with drainage facility, warm climatic conditions, disease free seeds and water sources. Varieties which are popular in India are Guntur Sannam, Bydagi, Kashmiri chilli, Jwala, Nalchetti, Hindpur and Sattur. However, problems for chilli cultivation faced by farmers likewise high labour charges, high cost of agricultural inputs, the low market price of chilli, pests and diseases, electricity problem. (Naik *et al*., 2019) [51]. For overcoming the problems in chilli cultivation it requires a particular approach for understanding the situation and factors influencing the Major biotic threats to chilli cultivation are Insects (thrips, whiteflies, aphids, *Helicoverpa* spp.), Mites (yellow mite, broad mite), Diseases (damping-off, choenophora blight, anthracnose, bacterial leaf spot and leaf curl virus) and root-knot

nematodes. Major Abiotic threats can be listed as nutrient deficiency, water deficiency etc. Successful chilli cultivation must have an integrated approach of all nutrient, water, insect and disease management that can overcome both the biotic & abiotic threats effectively. This paper contains a review of all the four management approaches listed in a single paper for profitable chilli cultivation. Mentioned approaches for better management of abiotic and biotic threats in chilli will be evaluated in future project (DST-SEED) which is being carried out at Piduguralla, Guntur, Andhra Pradesh (2021-2022).

Management of abiotic & biotic threats

Nutrient Management

Every crop requires essential nutrients for achieving good growth and yield. These nutrients are given in the form of manures either organic or inorganic. Organic manures include poultry manure, farm yard manure, neem cake etc. Inorganic manures include Urea, Murate of Potash, Single Super Phosphate etc. Several studies suggest that organic manures can help the soil for better nutrient uptake, yield and quality. Anitha, 1997 [4] reported that application of poultry manure enhanced the nutrient availability and gave better growth and yield in chilli. Neem cake application inclined the plant height, number of branches and also dry matter accumulation in chilli plants. (Sharu, 2000) [72] Vermicompost alone also gave best results in chilli in terms of growth and yield (Hiranmai and Vijayakumari, 2003) [26]. Soreng and Kerketta, 2017 [79] reported that 100% poultry manure application gave maximum growth than control in chilli. Kurubetta *et al*., 2017 [41] demonstrated that application of jeevamurta at transplanting, flowering, fruit initiation stages @ 550 litres/ha has recorded highest dry chilli yield (910 kg/ha) compare to other treatments. Organic manures not only increased the quality of chilli plants but also helped in declining the environmental pollution.

Whereas the application of inorganic fertilizers is considered as costly process and also causes environmental deterioration. Anyhow, few researchers claimed that best results were obtained after the application of inorganic fertilizers alone. Combination of 100 (N):90 (P2O5):90 (K2O): 20 (S):2 (Zn) kg/ha favoured the fresh chilli yield up to 20.57 tonnes/ha for two successive years (1996-1998). (Nirmal *et al.*,2003) [54] Application of 180 kg N/ha and 50 kg K/ha gave the highest yield up to 8.83 tons /ha. (Khan *et al.*,2014) [35] Application of inorganic fertilizers alone caused the imbalance of soil properties that resulted in low yield and high loss. This is very much key component to consider about the application of organic manures and inorganic manures alone. Few researchers affirmed that organic manures didn't change the plant height of chilli but the chlorophyll content and biomass content was high in organic fertilizer treated plants when compared to inorganic fertilizers treated plants. After the concern of the issues with both organic & inorganic manures, a new approach came into line i.e., combination of both organic manures & inorganic manures. Combination of both organic and inorganic manures increased the uptake of nitrogen when compared with organic manures alone. (Shashidhara, 2000; Kattamani, 2004) [73, 32] but can also favour the nutrient uptake efficiency. (Ghosh *et al.*, 2015) [22] 13-20% increase in the yield of vegetables was observed when treated with Microbial consortium which fixes N, P and Zn solubilizing bacteria also deducted the use of 25-30% fertilizers.(Magdoff and Van,2000) [43] Rao *et al*., 2015 [61] revealed that application of vermicompost, panchagavvya, azospirillium and phosphobacteria reduced the flower drop and inclined the yield in chilli. Application of RFD 75% + Farmyard manure + Sheep manure + Poultry manure + Vermicompost + Biofertilizers gave highest returns with BC ratio (4.47) in chilli. (Shabir *et al.,* 2017) [71] FYM @ 20 tonnes/ha applied along with 100% substitution of recommended dose of N (75 kg /ha) in organic form recorded maximum plant height, branches, and root spread. (Akshay *et al.*, 2018) Nchang *et al.*, 2018 depicted that 50% NPK, 50% FYM along with biofertilizers gave pod yield up to 194 quintals /ha in chilli. Application of 50% Urea, 50% Vermicompost and 50% FYM favoured the seedling growth to maximum when compared to control.(Mishra and Dayal, 2018) Kumar *et al*., 2019 [37, 38] found that combination of 120:60:50 of NPK +25tonnes FYM + Azospirillium/ha gave maximum plant height of 50cm, with 14 branches and 73 no. of leaves/plant in Andhra Jyothi G5 variety chilli. Shinde, 2020 [75] experimented the effect of seasol (seaweed biofertilizer) on chilli. His findings revealed that seasol @ 0.25% gave maximum yield.

Combination of NPK along with Poultry manure and biofertilizer (*Saccharomyces cerevisiae*) benefitted the chilli cultivation with better growth and higher yield. (Rivitra *et al*., 2021) [64] Thus, biofertilizers (Azospirillium, Phiosphobacteria, Seasol & *Saccharomyces cerevisiae)* also played keen role in the nutrient management for attaining best benefit cost ratio in chilli. Many researches are being carried out in terms of different factors like dosage of manures Pariari and Khan, 2013 [58] experimented on the different organic manures with different doses to find out the best combination. Their results depicted that 50% N from vermicompost + 50% N from urea gave the maximum yield i.e., 8.65 t/ha where as 75% N from neem cake and 25%N from urea gave the best quality chilli with ascorbic acid (177.60mg100-1g), Capsaicin (114.20 mg100-1g) contents. Wahoco *et al*., 2016 [94] studied about the effect of N levels in growth and yield of chilli, 250kg/ha N gave maximum plant height 69.6cm and also maximum no. of fruits per individual plant (163.66) but their findings also proved that there is no significant difference in the growth & yield of chilli treated with 250kg/ha and 150kg/ha & Application of organic manures at 2X (265.4 kg/ha) favoured the growth parameters of chilli plants but yield was better at 1X (132.7 kg/ha). (Wahoco *et al*., 2016; Khaitov *et al.,* 2019) [94, 34].

Method of applying the manures (Vermicompost applied with vermiwash & water in 1:1 ratio inclined the dry chilli yield. (Geroge, 2006) [21] Experimental findings revealed that organic manures (Vermicompost @ 2.5 tonnes/ha +FYM @ 12.5 tonnes/ha) when applied at basal dose achieved the maximum growth and yield when compared to control plots. (Reddy *et al.,* 2017) [62] and also novel products like Higrow which is supplement for macro and micro nutrients when sprayed at 7ml/litre of water gave the best results in terms of growth and yield of chilli as follows 67.86 cm plant height, 117.20 fruits per individual plant. (Baloch *et al.,* 2008) [9] Deore *et al.,* 2010 [17] developed a novel organic fertilizer which is made up of rice straw, neem cake, FYM, poultry waste, fish waste, press mud, rock phosphate and basalt dust. Micronutrients (Cu, Zn, Mg, Mn, Fe) and B were added separately as seed amino acid. This novel organic fertilizer at 3% dosage depicted the maximum growth and maximum yield in chilli. Aminochelates can be used as substitutes to synthetic fertilizers that excel the seedling growth at reduced

transplant growth period. (Souri and Sooraki, 2019) [80].
Overtime, an extensive literature has developed on the nutrient management of different crops as Integrated nutrient management which mainly focused on the fulfilment of nutrients to the crop precisely with novelty. Several products are reported in the literature to address this issue.

Water Management
Water plays crucial role in the plant development which can affect the quality and quantity of the produce. Proper amount of water supplied to the crop with accurate efficiency can also reduce the cost of cultivation. Resource management is the major concern at recent times and water management can directly affect the crop's health. Excess water can increase the chance of susceptibility to pests and diseases which can also favours the weed growth. Types of irrigation can be classified into two 1. Macro irrigation (surface, flood) 2. Micro irrigation (drip, sprinkler).

Surface irrigation
Excessive amount of water was utilised in surface irrigation when compared to drip irrigation. (Ashwani *et al.,* 2020) [6].

Drip irrigation
Drip irrigation minimizes the deep percolation, helps to reduce water wastage at initial stages of crop and reduces the evaporation till the harvest stage. (Kumar *et al*., 2011) [39, 40] Drip irrigation in chilli favoured 62% water saving and 44% incline in yield. Anon. (2018) [5]. Drip irrigation installed in chilli field increased the yield up to 48% and water consumption declined by 50% but when installed with mulch gave different results i.e., yield (32↑) & water consumption (28↓). (Nijamudeen and Dharmasena, 2002) [53] Drip irrigation noticeably increased the yield of chilli from 10-30% and saved water upto 43%. (Ashwani *et al.,* 2020) [6] Drip irrigation alone undoubtedly benefitted the chilli farmers with good yield and returns. A closer look to the literature on fertigation schedules in chilli. however, reveals that a number of gaps and short comings. the dosage of the fertilizers used in the drip, selection of fertilizers to be used and plan of schedule for the nutrient requirements must be addressed and more research has to be done to fulfil the different varieties of chillies cultivated. Seminal contributions on fertigation of chilli plants have been made by Deolankar and Firake, 1999 [16] worked on the fertigation method in chilli.
Their study was to provide the soluble solid fertilizers through the fertigation process and recorded the growth parameters accordingly. However, the plant growth was higher in 125% RDSF with recorded plant height (89.70cm) followed by 100% RDSF with recorded plant height (87.04cm). Veerana *et al*., 2000 [91] presented in *Conf. on Spices and aromatic plants* about the cultivation of chilli through fertigation gave higher yield than the conventional cultivation and their findings in the next successive year revealed that 80% RDF through drip fertigation gave up to 1268kg/ha dry chilli yield which was presented at *Changing scenario in the production systems of horticultural crops*. *Proceedings National Seminar* (2001) at Coimbatore, Tamil Nadu, India. Tumbare and Bhoite, 2002 [88] recorded the highest yield in the cultivation of chilli through 100% RDF by drip irrigation with recorded benefit cost ratio as 2.17 when compared with normal surface irrigation. Tumbare and Nikam, 2004 [87] recorded the higher yield up to 9.18 tonnes/ha through fertigation method in chilli. Irrigation was provided once for every two days with RDF was the possible reason for such yield. Selva Kumar, 2006 studies revealed that benefit cost ratio reached up to 3.30 in chilli with combination of 100% WRc (computed water requirement of crop) + 100% RDF through fertigation. Muralikrishnasamy *et al*., 2006 [49] reported that dry chilli yield was higher in drip fertigation method (50% pan evaporation + 100% N& K) as 2222kilos/ha but the surface irrigation combined with NPK soil application gave 1327kilos/ha dry chilli yield. Mahajan *et al*., 2007 [44] studies revealed that 100% RDN (recommended dose of nitrogen) when supplied through drip irrigation (277.4 quintals/ha) gave superior yield when compared with check basin irrigation (216.1 quintals/ha) in chilli. Vijaykumar *et al.*, 2010 treatment with 75% Pan evaporation+ 75% RD of N & K inclined the growth & yield of chilli when provided water for 5 days in a week at 50% Evapo transpiration. Chilli's BC ratio was 3.8 under drip irrigation with 1 lateral for each row on the raise bed conditions. (Nadiya *et al.,* 2013) [50] Ashwani *et al.,* 2020 [6] depicted the highest yield of chilli i.e., 10.69 tonnes/ha was produced through daily drip irrigation with 125% RDN and marginal saline water. Highest BC ratio was obtained by when treated with 80% Irrigation Water Requirement +100% RDF in chilli cultivation. (Gireesh *et al.*, 2020) [24]
In short literature pertaining to above researchers strongly suggests that drip irrigation can be efficient water management strategy for cultivation of chilli with minimal water usage, incline in the yield and cut short the inputs for chilli cultivation. This can also be more efficient when fertilizers are supplied through drip at exact doses but more research has to be done when it comes for fertigation dosages, schedules to achieve the best results. Limitations persists when it comes to quality of water and available of water resource, adoption to the technology and also capital cost.

Insect Management
Main pests of chilli are aphids (*Myzus persicae* & *Aphis gossypi*), mites (*Polyphagotarsonemus latus)*, thrips *(Scirtothrips dorsalis*) and whitefly (*Bemisia tabaci*). (Berke and Shieh, 2000) [10] They cause very drastic economic loss to the chilli farmers when affected. Few more pests also infest the chilli crop *viz*., *Helicoverpa armigera*, *Tobacco caterpillar* etc. Prevention and early identification can diagnose the infestation up to remarkable level. For the instance, the following studies were conducted on the insect pest management of chilli.

Thrips
Basic symptom for the thrips infestation is upward curling of leaves due to sucking of cell sap by adults & larvae of thrips. (Sanap and Nawale,1987) [65] But at heavy infestation leaves become tender and buds turn out to brittle which leads to shedding of leaves and yield loss that can appear as chilli leaf curl disease. (Amin, 1979) [3] Chilli thrips infestation causes silvery leaf surface, leaf lamina thickening, brown frass markings on leaves, petiole and fruits, ring like scarred tissue around the apex of fruits and distorted fruits with premature falling of leaves. (EPPO, 2005) [20] Mahalingappa *et al*., 2008 [45] evaluated few chemicals against mites and thrips in chilli. Results revealed that Profenofos@ 0.10% was most effective against mite infestation. Thrips population was effectively controlled by fipronil @ 0.01% and triazophos@ 0.08% than ethion, cypermethrin and chloropyriphos. Mandi and Senapati, 2009 [46] reported that use of acetamiprid gave highest yield (40.5quintals/ha) with highest cost benefit ratio

1:16.97 by controlling thrips infestation. Fipronil @ 50gm ai. /ha recorded least% of thrips in chilli with no phytotoxic effects in chilli but fipronil @ 30gm ai. /ha gave poor control. (Reddy and Sreehari, 2009) [63] Prabhu *et al.*, 2015 revealed that Imdiacloprid 17.8% SL effectively managed chilli thrips population 250 ml /ha with 25% increase in green chilli yield. Chlorphenapyr + White sticky trap treated plots recorded least percentage infestation of upward curl (19.05%) and downward curl (21.08%) while the control plot recorded highest percentage of upward curl (71.25%) and downward curl (82.38%) in chilli. (Hossain *et al.*, 2016) [27] Devi *et al.*, 2017 [19] demonstrated that least infestation of thrips and mites was found after the application of organic manures *viz*., vermicompost and neem cake. Thrips population was controlled by spinosad@0.015% and got yield up to 272.33 quintals/ha. (Devi *et al.*, 2017; Seal *et al*., 2006; Meena and Tayde, 2017) [19, 67, 47] Dale and Borden, 2018 reported that Chlorantraniliprole controlled the chilli thrips population with minimal risk to natural enemies.

Mites

Border crops *viz*., maize, agathi and sunflower were reported as best barrier crops against mites in chilli. (Nelson and Natarajan, 1994) [52] Ahmed *et al*., 2001 [2] studies revealed that neem oil application @ 5ml/litre recorded 34.2% reduction of chilli mite over control. Combined application of (Neem cake+ vermicompost+50% NPK) recorded higher yield and least infestation of thrips and mites in chilli. (Varghase, 2003; Giraddi and Smitha,2004) [89, 23] Mite population was high from Mid- September to Mid -October in chilli.(Vichitbandha and Chandrapatya,2011) Bio efficacy of acaricides(dicofol) inclined when mixed with plant oils. (Veena *et al*., 2017) [90] Combination of Fipronil 5% + Buprofezin 20% SC @ 100+400g a.i./ha has recorded the lowest number of chilli mite population. (Kumar *et al.*, 2019) [37, 38] Combination of spirotetramat + diafenthiuron @ 75+300g a.i./ha recorded least mite incidence as compared to other treatments. (Kotresh *et al.*,2020) [36].

Whiteflies & Aphids

White flies suck the cell sap from leaves causing yellowing and crumpling which eventually causes stunted growth and distorted fruits. (Sani *et al.*,2020) [66] Planting border crops i.e., South African tall maize (SATM) (3 rows thick all along the main crop) controlled the sucking pest infestation and gave higher yields. (Gundannavar *et al*.,2010; Tatagar *et al.*,2011; Sujay *et al.*, 2015) [25, 85, 83] Sucking pest incidence in chilli was lowest when intercropped with coriander, cotton and onion that claimed higher yields in chilli. (Aswathanarayanareddy *et al.*,2006) [7] Maize and brinjal when intercropped with chilli reduced the aphid incidence in chilli. (Hussein and Samad,1993) [29] Bio efficacy of chlorfenapyr 240 SC, emamectin benzoate 5% SG and imidacloprid 17.8 SL was evaluated on the control of white fly population in chilli. Their studies revealed that maximum yield obtained in the plots treated with chlorfenapyr 240 SC but BC ratio was high in emamectin benzoate 5% SG treated plots. (Jain *et al.*,2018) [30] Chemical treatments with systemic insecticides *viz*., clothianidin, dinotefuran, imidacloprid, thiamethoxam, chlorantraniliprole, spinosad, and flupyraifurone has better control over the white fly population. (Shindhe *et al*., 2016; Avery *et al.*, 2019 [8]; Smith *et al*., 2019) Entomopathogenic fungi *viz*., *Beauveria bassiana* and *Metarhizium anisopilae* can effectively control the white fly population as symbiotic endophytes and considered as future strategy in IPM. (Sani *et al.*, 2020) [66] Bio rationals *viz*., *Beauveria bassiana, Lecanicillium lecanii* & *Metarhizium anisopliae* not only reduced the white fly population but also controlled the aphid population in capsicum. (Singh and Josh, 2020) [76, 77].

In addition, these findings provide information about the idea of controlling the major pests in chilli in an integrated manner. Agronomic practices like crop rotation, deep ploughing, weed control, proper spacing, destroying debris and planting border crops can collectively prevent the infestation of almost all pests in chilli. Botanical extracts like neem seed extract, neem cake and Entomopathogens like *Beauveria bassiana*, *Verticillium lecanii* at recommended doses managed the pest population in chilli with minimal environmental pollution. Few insecticides were also noticeably controlled the pest population in chilli with minimal damage to natural enemies but chemicals were never the best option because of residual effects and also resurgence nature.

Disease Management

Fungal

Choanephora blight is the one of the serious diseases in chilli which causes die back, wet rot, soft tissues on stem and root that can eventually lead to poor yield. (Maeda *et al.*, 2010) [42] Captan @ 0.15% was found to be effective against twig blight in chilli at field conditions. (Panja, 1999) [57] where as in green house conditions Trichoderma was found to be effective. (Chandrakala *et al.*, 2018) [13] Leafspot in chilli caused by *Alternaria spp*.& *Cercospora capsici* were controlled effectively when treated with Tilt 25% EC @ 0.05% + Eucalyptus spp. @ 10% + Pseudomonas fluorescens @ 5g/ lt. (Devappa and Thejakumar,2016) [18] Fungicide carbendazim have controlled disease incidence of chilli anthracnose than the botanical formulations at lower doses in chilli. But in inhibiting spore germination ginger chloroform performed well *in vitro* conditions. (Choudhury *et al.*, 2017) [14] Chilli anthracnose is one among major diseases in chilli which can cause 50% crop loss. (Pakdeevaraporn *et al.*, 2005) [55] Integrated disease management approach can effectively manage chilli anthracnose rather than single strategy approach. Integrated approach includes Use of disease resistant planting material, rotating with non-solanaceous crops for at least 2 years and destroying the plant debris [84]. Management of chilli anthracnose was done by soaking the chilli seeds for 12 hours in 0.2% thiram. (Chakravarthy and Anilkumar, 1975) [12] Usage of single chemical can lead to resistance rapidly. (Staub, 1991) There after few fungicides came into existence for controlling the chill anthracnose *viz*., including 0.2% mancozeb, 0.1% ziram, Blitox 50, 0.1% Bavistin and 0.5% or 1% Bordeaux mixture as seed dressing agents. *Trichoderma spp* have effectively controlled the chilli anthracnose. (Boonratkwang *et al.*, 2007) [11] Next level of strobilurin fungicides (azoxytrobin, trifloxystrobin and pyraclostrobin) have managed the anthracnose disease in chilli. (Than *et al.*, 2008) [86]

Bacterial

Bacterial leaf spot caused by *Xanthomonas spp* is destructive disease in chilli which can cause total crop loss at warm and humid climatic conditions. Symptoms are developed as lesions on the leaves which are tan to brownish red in colour. Lesions may also possess yellow halo around. Group of

lesions combine to form large necrotic tissue which may eventually lead to defoliation. Spots may also occur on the infected fruits. Bacterial disease can be managed by planting disease seeds, avoiding excess irrigation to prevent the disease and not recommending the host crops like tomato and chilli within 3 years after noticing the disease in the field. (Sun *et al.,* 2002) [84]

Viral

Chilli Leaf Curl Virus Disease (ChiLCVD) is the serious threat to chilli plants which can cause 100% yield losses at severe infection. (Senanayake *et al.,* 2007; Kumar *et al*., 2011) [69, 39, 40] Symptoms of leaf curl virus was recorded as upward curling, limited plant growth, thickened leaf lamina and vein clearing in chilli. (Senanayake *et al.,* 2012) [70] Anyhow viral diseases are always prevented from destroying the plants by controlling the vectors of virus. Vectors of chilli leaf curl virus were controlled by chemical methods *viz*., Diafenthiuron @ 200 ml/litre, Imidacloprid 17.8 SL (0.003%), Imidacloprid (0.05%), acephate (0.1%) and Malathion (0.05%). (Hussain *et al.,* 2017; Pandey *et al*., 2010; Ahmed and Ram, 2016) [28, 56, 94] botanical methods *viz*., Need seed kernel extract @5%, Seed extract of *Sapindus trifoliatus* and *Solanum trilobatum*). (Pandey *et al.,* 2010; Ahmed and Ram, 2016) [56, 94] Cultural practices like proper seed selection, discarding the infected seedlings, protecting the seedlings in nurseries, proper weed control, yellow sticky traps etc. can effectively prevent the virus in chilli. (Kenyon *et al.,* 2014)

Conclusion

Overall summary of this paper concludes that chilli cultivation can be trouble-free and profitable when cultivated in an integrated manner. However, combined approach of management practices can give quick and affordable solutions to the biotic and abiotic threats in chilli cultivation. Abiotic threats (water related problems & nutrient related problems) can be maintained by choosing right system of irrigation and selective fertilizers. Drip irrigation can be a possible solution for efficient cultivation of chilli which can save the water consumption and prevent weeds and pests. Nutrients can be managed by combining both the organic and inorganic manures along with biofertilizers which can incline the nutrient uptake capacity and maintain good soil conditions for sustainable use. Well-maintained nutrient approach also favours the quality and quantity of the yield in chilli. Biotic threats (Insects & diseases) can be maintained by choosing the eco-friendly management practices which can fulfil two or more requirements of chilli crop. For an example, Neem cake application acted as supplement of nitrogen and also managed the thrips & mite infestation in chilli. This type of management practices can diminish the cost of inputs and improves the yield. Deep exploration is essentially required for choosing the best management practices in chilli cultivation which can reduce the cost of inputs, labour charges and improves the quality and quantity of yield.

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