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Novel management strategy to minimize the growing threat of fruit rot and powdery mildew diseases of chilli (*Capsicum annuum*) in India

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Abstract
Chilli (*Capsicum annuum* L.), is severely infected by anthracnose (*Colletotrichum capsici*) and powdery mildew (*Leveillula taurica*), which significantly reduces the quality and yield of chilli in India, especially in the recent years. The concern of modern plant breeding for improvement of new varieties with escape behavior to diseases or genetic resistance, but currently, the use of chemicals offers a practical and rapid solution to combat the disease outbreaks. Compounds having a novel mode of action are of special interest, since they play a key role in resistance management strategies with enhanced characteristics such as systemicity and longer protection period in plant disease management. In the present study, an experiment was conducted for the management of fruit rot and powdery mildew in chilli at Horticulture Research and Extension Center, Devihosur, Haveri, Karnataka, India. Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC @ 0.05% recorded significantly least per cent disease index and significantly highest dry yield of chilli compared to all other treatments. It has also recorded significant improvement in quality parameters such as increase in capsanthin and capsaicin content along with improved plant health characters such as prolonged greening and greater dry mater production. The untreated check recorded significantly highest per cent disease index and least dry yield of chilli. The technical feature of this fungicide will provide useful information for stakeholder for target specific action against anthracnose and powdery mildew diseases along with improved plant health, quality and increase in yield.

Keywords: Chemical, chilli, fruit rot, management, powdery mildew

1. Introduction

Chilli, botanical called *Capsicum annuum* (2n=24) belongs to *Solanaceae* family. It is an indispensable spice and used as basic ingredient in a great variety of cuisines. Chillies are rich in vitamins and are also packed with potassium, magnesium and iron. They have long been used as pain relief as the extracts of chilli peppers are used for alleviating the pain of arthritis, headaches, burns and neuralgia. It also has the property to boost immune system.

India, China, Ethiopia, Mexico, Vietnam, Pakistan and Bangladesh accounted for more than 85% of the world production. India is the largest producer and exporter of chilli, grown over an area of 0.794 million hectares with an annual production of 0.13 million tonnes with the productivity of 1.5 tonnes/ha (Anonymous, 2014) [3]. The important states growing chilli are Andhra Pradesh, Karnataka, Maharashtra, West Bengal, Rajasthan and Tamil Nadu. Karnataka ranks second in area and production of dry chilli [(100.73 ('000 ha) and 107.00 ('000 MT)] after Andhra Pradesh (Anonymous, 2014) [3]. In Northern Karnataka, chilli production is highly concentrated in the districts like Dharwad, Gadag, Haveri, Koppal, Ballari and Raichur.

Byadgi chilli varieties grown in Karnataka are well known for quality throughout the world. They possess a unique characteristic flavor and aroma, high colour (175-180 ASTA units) and oleoresin with very less pungency, which makes it the best variety for oleoresin extraction and chilli powder industries. Quality wise it is comparable only to Paprika varieties grown in European countries. There is lot of demand for these chillies both in domestic and international market. Nearly 75 per cent of Byadgi chillies sold in the market are exported in either direct or indirect forms. In 2018-19, around 4 - 5 lakh tonnes of chilli was exported to countries like China, Sri Lanka, Bangladesh, U.A.E, Malaysia, Vietnam and Thailand. For 2019-20, the chilli exports are halted due to COVID 19.

Unfortunately, chilli suffers from many diseases caused by fungi, bacteria, viruses and nematodes. Among the fungal diseases anthracnose or fruit rot caused by *Colletotrichum capsici* and powdery mildew caused by *Leveillula taurica* are most prevalent. These diseases have attained the economic status in the Karnataka state by considering the disease severity, economic damage and exorbitant losses caused by them. The *Colletotrichum capsici* cause severe damage to ripened fruits and reduce the quality and quantity of immature and mature fruits. The economic losses are high due to pre and post harvest involvement of the pathogen causing 10-80 per cent of the marketable yield loss of chilli fruits (Than *et al*., 2008) [36]. Anthracnose disease is the most damaging disease of chilli reducing marketable yield up to 80 per cent (Poonpolgul and Kumphai, 2007) [28]. Due to anthracnose, more than 50 per cent crop loss has been reported from different parts of India (Ramchandran *et al*., 2008) [29]. The disease has been reported to cause 19-59 per cent yield loss in Karnataka, 20-60 per cent in Punjab and Haryana and 30-76 per cent in Tamil Nadu (Shilpa and Mesta, 2017) [33].

2. Materials and methods

2.1 Study area and location

The experiment was laid down in randomized block design with three replications at Horticulture Research and Extension Center, Devihosur, Haveri, Karnataka, India (: 14°47' North Latitude and 75°21' East Longitude). This research center is exclusively working on dry chilli especially on byadgi cultivar, as it is one of the most important variety preferred by the consumers both in domestic and international market. The area of individual plot was 17.28 m^2. Field trial was set up under naturally occurring inoculum of anthracnose (*Colletotrichum capsici*) and powdery mildew (*Leveillula taurica*) as it is one of the important hot spot for both the diseases.

2.2 Plant material and application of fungicides

Seedlings of chilli cv. Byadgi Dabbi were planted in the experimental plot (4.8 m x 3.6 m) with a spacing of 0.6 m x 0.6 m. First spray was given immediately after the initial symptoms of disease were observed and remaining two sprays were given at 15 days interval. Control was maintained with no fungicidal spray. The percent disease was measured using 0-9 disease rating scale as per phytopathometry (Mayee and Datar, 1986) [25]. Per cent disease index was calculated to as per the formula given by Wheeler (1969) [38].

3. Results

3.1 Bio-efficacy

The effect of Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC on fruit rot and powdery mildew diseases of chilli during the year 2016 and 2017 are presented below in the respective tables.

3.1.1 Bio-efficacy of Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC on fruit rot and powdery mildew diseases of chilli during the year 2016

The incidence of fruit rot differed significantly with respect to all the treatments at all stages of observation. Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC @ 300 ml/ha recorded significantly least per cent disease index of 6.6% and it was on par with Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC @ 250 ml/ha (9.62% PDI). The untreated check recorded significantly highest per cent disease index of 24.42% (Table 1 and Figure 1).

Similarly, the severity of powdery mildew differed significantly with respect to all the treatments at all stages of observation. Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC @ 300 ml/ha recorded significantly least per cent disease index of 7.40% and it was on par with Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC @ 250 ml/ha (9.62% PDI). The untreated check recorded significantly highest per cent disease index of 21.46% (Table 2 and Figure 1).

3.1.2 Bio-efficacy of Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC on fruit rot and powdery mildew diseases of chilli during the year 2017

The incidence of fruit rot differed significantly with respect to all the treatments at all stages of observation. Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC @ 300 ml/ha recorded significantly least per cent disease index of 8.14% and it was on par with Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC @ 250 ml/ha (10.36% PDI). The untreated check recorded significantly highest per cent disease index of 25.90% (Table 1).

Similarly, the severity of powdery mildew differed significantly with respect to all the treatments at all stages of observation. Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC @ 300 ml/ha recorded significantly least per cent disease index of 9.62% and it was on par with Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC @ 250 ml/ha (12.58% PDI). The untreated check recorded significantly highest per cent disease index of 34.78% (Table 2).

3.2 Dry yield of chilli

3.2.1 Effect of Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC on dry yield of chilli during 2016

The treatments differed significantly with respect to yield of dry chilli. Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC @ 300 ml/ha recorded significantly highest dry yield of chilli (7.17 q/ha) than all the treatments and it was on par with Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC @ 250 ml/ha (7.04 q/ha). The untreated check (3.41 q/ha) recorded significantly least dry yield of chilli (Table 3).

3.2.2 Effect of Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC on dry yield of chilli during 2017

The treatments differed significantly with respect to yield of dry chilli. Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC @ 300 ml/ha recorded significantly highest dry yield of chilli (9.65 q/ha) than all the treatments and it was on par with Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC @ 250 ml/ha (9.07 q/ha). The untreated check (3.76 q/ha) recorded significantly least dry yield of chilli (Table 3).

3.3 Plant health and quality parameters

The laboratory analysis on quality parameters such as colour and pungency content in chilli fruits revealed that there was significant increase in both colour and pungency content when treated with the test chemical. The treatments differed with respect to colour and pungency content in chilli fruits. Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC @ 250 ml/ha recorded highest colour and pungency content (231 ASTA and 6369 SHU respectively) than compared to carbendazim 50% WP (201 ASTA and 4128 SHU respectively). Further, it was observed that there was significant improvement in plant health characters such as prolonged greening, flowering and fruiting (Table 5 and Figure 1).

3.4 Phytotoxicity
No phytotoxicity symptoms were observed at all stage of crop growth by application of the test chemical Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC of any concentration at 1, 3, 5, 7 and 10 days after the application (Table 4).

4. Discussion
In the present study, Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC @ 250 ml/ha was found effective in controlling fruit rot and powdery mildew without any symptoms of phytotoxicity with significant increase in dry yield of chilli. It has also shown significant improvement in plant health such as prolonged greening and greater dry mater production and quality parameters such as increase in capsanthin and capsaicin content resulting in better market price and higher profit margin.

Similar results were found in the literature, Santoshreddy *et al*., 2014 [31] reported that among the three systemic fungicides evaluated at 0.2% concentration, pyraclostrobin 20% WG shown least infection (11.63%) of fruit rot and highest vigour index (861.17) in chilli. Abdul Kareem *et al*., 2016 [1] reported that pyraclostrobin 20% WG @ 375 g/ha recorded significantly least per cent disease index of fruit rot and significantly highest dry yield of chilli (7.05 q/ha). Difenconazole 25% EC @ 0.05% (28.62 PDI) recorded significantly least per cent disease index of fruit rot and powdery mildew (Abdul Kareem *et al*., 2017) [2]. Pyraclostrobin produced more fruits with higher productivity. Increases in productivity by the application of strobilurins have also been reported in tomatoes (Cantore *et al*., 2016) [9], grapes (Berkelmann-Loehnertz *et al*., 2001; Diaz-Espejo *et al*., 2012) [6, 12], wheat (Ishikawa *et al*., 2012; Jorgensen and Olesen, 2002; Kildea *et al*., 2010; Ruske *et al*., 2003) [17, 19, 20, 30], corn (Barbosa *et al*., 2011; Blandino *et al*., 2012) [4], beans (Jadoski *et al*., 2015; Kozlowski *et al*., 2009) [18, 22] and soybeans (Fagan *et al*., 2010; Soares *et al*., 2011) [13, 34]. The higher production of fruits of these plants was possibly due to the greater assimilation of carbon dioxide and better use of nitrogen.

Pyraclostrobin belongs to quinone or strobilurin class of fungicides, which disrupts fungal mitochondria activity, prevent spore germination and reducing mycelial and growth (Bartlett *et al*. 2002) [5]. In addition, strobilurins have also been shown to induce physiological ‘‘plant health’’ effects (e.g., growth stimulation, hormonal changes, and delayed senescence) that could contribute to increased yields (Koehle *et al*. 2002; Venancio *et al*. 2003) [21, 37]. The strobilurin treated plants recorded prolonged ‘‘greening’’ (Kyveryga *et al*. 2013) [24]. Significantly greater dry matter accumulation and increase in yields as more photosynthetically efficient leaves are retained for longer period (Morrison et al. 1999; Specht *et al*. 1999; Kumudini *et al*. 2001) [26, 35, 23]. The strobilurin induced physiological effects was demonstrated in soybean (Conrath *et al*. 2004; Nason *et al*. 2007; Fagan *et al*. 2010) [13].

As with strobilurin, it was observed that boscalid temporarily decreases plant respiration, which resulted in an increase in the net assimilation rate of carbon dioxide and an increase in the activity of the nitrate reductase enzyme. In addition to the improvement of nitrogen metabolism, strobilurins also act on the hormonal balance of plants, as they reduce the synthesis of ethylene and increase the synthesis and decrease the degradation of cytokinins. As a result, these plants present a reduction of chlorophyll degradation, causing what is called a “green effect”, delaying the yellowing of the leaves caused by the degradation of chlorophyll (Grossmann *et al*., 1999; Grossmann and Retzlaff, 1997; Ruske *et al*., 2003 and Sarwat *et al*., 2013) [30, 32]. In grapes (Berkelmann-Loehnertz *et al*., 2001) [6], corn (Blandino *et al*., 2012), soybeans (Fagan *et al*., 2010) [13] and beans (Jadoski *et al*., 2015) [18], the application of different strobilurins also increased carbon dioxide assimilation rates.

The reduction of chlorophyll degradation, combined with better nitrogen utilization, slows plant senescence and contributes to the increase in the net assimilation rate of carbon dioxide, since chlorophyll is an essential component for photosynthesis (Hortensteiner and Krautler, 2011) [16]. Increased photosynthetic activity in the leaves was the main factor for the increase in productivity of the plants treated with strobilurins, since the delay in senescence, even for a few days, tends to increase production (Bertelsen *et al*., 2001).

The application of azoxystrobin also decreased the rate of net carbon dioxide assimilation, transpiration rate and stomatal conductance in wheat (Nason *et al*., 2007), barley (Nason *et al*., 2007), soybean (Nason *et al*., 2007) and rice (Debona *et al*., 2016). Similarly, in soybean (Soares *et al*., 2011) [34] and corn (Barbosa *et al*., 2011) [4], increase in nitrate reductase enzyme activity occurred.

Table 1: Bio-efficacy of Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC on fruit rot disease of chilli

Sl. No.	Treatments	Dosage (per ha)		Fruit rot (PDI)		
		a. i. (g)	Formulation (g)	2016	2017	Pooled
1.	Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC	75	150	15.54 (23.22)	16.28 (23.80)	15.91(23.50)
2.	Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC	100	200	13.32 (21.41)	13.32 (21.41)	13.32(21.41)
3.	Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC	125	250	9.62 (18.07)	10.36 (18.78)	9.99 (18.42)
4.	Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC	150	300	6.66 (14.96)	8.14 (16.58)	7.40 (15.78)
5.	Pyraclostrobin 20% WG	100	500	10.36 (18.78)	14.06 (22.02)	12.21(20.45)
6.	Fluxapyroxad 300 g/l SC	62.5	209	11.10 (19.46)	15.54 (23.22)	13.32(21.41)
7.	Hexaconazole 5% EC	25	500	10.36 (18.78)	14.80 (22.63)	12.58(20.77)
8.	Carbendazim 50% WP	250	500	11.84 (20.13)	18.50 (25.47)	15.17(22.92)
9.	Control	-	-	24.42 (29.61)	25.90 (30.59)	25.16 (30.10)
SE.m ±				1.05	1.30	0.90
CD at 5 %				3.14	3.70	2.70
CV				14.41	14.04	11.21

Figures in parenthesis are arcsine transformed values

Table 2: Bio-efficacy of Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC on powdery mildew of chilli

Sl. No.	Treatments	Dosage (per ha)		Powdery Mildew (PDI)		
		a. i. (g)	Formulation (g)	2016	2017	Pooled
1.	Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC	75	150	14.80 (22.63)	19.98 (26.55)	17.39(24.64)
2.	Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC	100	200	11.84(20.13)	15.54(23.22)	13.69(21.71)
3.	Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC	125	250	9.62 (18.07)	12.58(20.77)	11.10(19.46)
4.	Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC	150	300	7.40 (15.79)	9.62(18.07)	8.51(16.90)
5.	Pyraclostrobin 20% WG	100	500	11.84 (20.13)	17.02 (24.37)	14.43 (22.32)
6.	Fluxapyroxad 300 g/l SC	62.5	209	12.58 (20.77)	18.50 (25.47)	15.54 (23.21)
7.	Hexaconazole 5% EC	25	500	10.36 (18.78)	14.80 (22.68)	12.58 (20.77)
8.	Carbendazim 50% WP	250	500	13.32(21.41)	22.94(28.62)	18.13(25.20)
9.	Control	-	-	21.46 (27.60)	34.78 (36.14)	28.12 (32.02)
SE.m ±				0.85	1.51	0.95
CD at 5 %				2.56	4.52	2.86
CV				11.76	14.18	10.67

Figures in parenthesis are arcsine transformed values

Table 3: Effect of Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC on dry yield of chilli

Sl. No.	Treatments	Dosage (per ha)		Dry Yield (q/ha)			Percent increase in yield over control (%)	Benefit cost ration
		a. i. (g)	Formulation (g)	2016	2017	Pooled		
1.	Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC	75	150	5.45	7.81	6.63	84.64	2.52
2.	Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC	100	200	5.98	8.49	7.23	101.35	2.67
3.	Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC	125	250	7.04	9.07	8.05	124.19	2.88
4.	Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC	150	300	7.17	9.65	8.41	134.21	2.93
5.	Pyraclostrobin 20% WG	100	500	6.25	6.46	6.36	77.12	2.34
6.	Fluxapyroxad 300 g/l SC**	62.5	209	5.73	6.08	5.90	64.31	0.00
7.	Hexaconazole 5% EC	25	500	5.41	5.79	5.60	55.96	2.30
8.	Carbendazim 50% WP	250	500	5.07	4.82	4.95	37.85	2.00
9.	Control	-	-	3.41	3.76	3.59	-	1.50
SE.m ±				0.24	0.34	0.21	-	-
CD at 5 %				0.73	1.03	0.63	-	-
CV				7.34	8.61	5.80	-	-

** Product commercially not available in the market

Table 4: Phytotoxicity of Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC on chilli

Sl. No.	Treatments	Phytotoxicity symptoms At 1, 3, 5, 7 and 10 Days after application of test chemical																													
		Yellowing					Leaf tip injury					Chlorosis					Wilting					Epinasty					Hyponasty				
		1	3	5	7	10	1	3	5	7	10	1	3	5	7	10	1	3	5	7	10	1	3	5	7	10	1	3	5	7	10
1	Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC @ 250 ml/ha	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC @ 500 ml/ha	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	Control	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 5: Effect of Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC on quality parameters of chilli

Sl. No.	Treatments	Colour (ASTA units) Mean values	Pungency (SHU) Mean values
1	Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC@ 250 ml/ha	231	6369
2	Carbendazim 50% WP @ 500 g/ha	201	4128

Fig 1: Bio-efficacy of Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC on fruit rot and powdery mildew diseases of chilli

5. Conclusion

Based on the results obtained, it was concluded that the fungicide treatments presented different responses in chilli. The new test fungicide, Fluxapyroxad 250 g/l + Pyraclostrobin 250 g/l 500 SC @ 250 ml/ha was found effective in controlling fruit rot and powdery mildew diseases of chilli without any symptoms of phytotoxicity with enhanced characteristics such as systemicity and longer protection period in plant disease management with increase in dry yield of chilli. It has also shown significant improvement in quality parameters such as increase in color content *i.e.*, capsanthin and pungency *i.e.*, capsaicin. The physiological benefits were more evident with test fungicide, and these benefits manifested in terms of increased fruit production and improved quality of the produce. The higher productivity probably occurred due to the better physiological performance of these plants.

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7. References

1. Abdul Kareem M, Tatagar MH, Krishna Kurubetta, Raghavendra Mesta, Dileepkumar Masuthi. Evaluation of bio-efficacy and phytotoxicity of pyraclostrobin 20% WG against anthracnose disease of chilli. Journal of Pure and Applied Microbiology 2016;10(3):2397-2399.
2. Abdul Kareem M, Krishna Kurubetta, Ajjappalavara PS, Tatagar MH, Shweta K. Evaluation of bio-efficacy and phytotoxicity of difenconazole 25% EC against die back, fruit rot and powdery mildew diseases of chilli. Int. J. Curr. Microbiol. App. Sci 2017;6(8):477-480. doi: 10.20546/ijcmas.2017.608.062.
3. Anonymous. Directorate of economics and statistics, New Delhi 2014.
4. Barbosa KA, Fagan EB, Casaroli D, de Carvalho Canedo, S, Teixeira WF. Aplicação de estrobilurina na cultura do milho: alterações fisiológicas e bromatológicas. Rev. Centro Univ. Patos de Minas 2011;2:20-29.
5. Bartlett DW, Clough JM, Godwin JR, Hall AA, Hamer M. The strobilurin fungicides. Pest Manag. Sci 2002;58:649-662. doi: org/10.1002/ps.520.
6. Berkelmann Loehnertz B, Dorn C, Baus Reichel O, Griebel T. Impact of strobilurins on grapevine physiology under greenhouse conditions. IOBC WPRS Bull 2001;24:303-307.
7. Bertelsen JR, De Neergaard E, Smedegaard-Petersen V. Fungicidal effects of azoxystrobin and epoxiconazole on phyllosphere fungi, senescence and yield of winter wheat. Plant Pathol 2001;50:190-205. doi: org/10.1046/j.1365-3059. 2001.00545.x.
8. Blandino M, Galeazzi M, Savoia W, Reyneri A. Timing of azoxystrobin + propiconazole application on maize to control northern corn leaf blight and maximize grain yield. Field Crops Res 2012;139:20-29. doi: org/10.1016/j.fcr.2012.09.014.
9. Cantore V, Lechkar O, Karabulut E, Sellami MH, Albrizio R. Combined effect of deficit irrigation and strobilurin application on yield, fruit quality and water use efficiency of cherry tomato (*Solanum lycopersicum* L.). Agric. Water Manage 2016;167:53-61. doi: 10.1016/j.agwat.2015.12.024.
10. Conrath U, Amoroso G, Kohle H, Sultemeyer DF. Non-invasive online detection of nitric oxide from plants and some other organisms by mass spectrometry. Plant J 2004;38:1015-1022.
11. Debona D, Nascimento KJT, Gomes JGO, Aucique-Perez CE, Rodrigues FA. Physiological changes promoted by a strobilurin fungicide in the rice-bipolaris oryzae interaction. Pestic. Biochem. Physiol 2016;130:8-16. doi:org/10.1016/j.pestbp.2015.12.006.
12. Diaz Espejo A, Cuevas MV, Ribas Carbo M, Flexas J Martorell. The effect of strobilurins on leaf gas exchange, water use efficiency and ABA content in grapevine under field conditions. J. Plant Physiol 2012**;**169:379–386. doi: 10.1016/j.jplph.2011.11.014.
13. Fagan EB, Dourado Neto D, Vivian R, Franco RB. Yeda MP. Efeito da aplicação de piraclostrobina na taxa fotossintética, respiração, atividade da enzima nitrato redutase e produtividade de grãos de soja. Bragantia 2010;69:771-777. doi: org/10.1590/S0006-87052010000400001.
14. Grossmann K, Kwiatkowski J, Caspar G. Regulation of phytohormone levels, leaf senescence and transpiration by the strobilurin kresoxim-methyl in wheat (*Triticum aestivum*). J Plant Physiol 1999;154:805–808. doi:org/10.1016/S0176-1617(99)80262-4.
15. Grossmann K, Retzlaff G. Bioregulatory effects of the fungicidal strobilurin kresoxim-methyl in wheat (*Triticum aestivum*). Pestic. Sci 1997, 2-8.

doi: org/10.1002/(SICI)1096-9063(199705)50:1<11::AID-PS556>3.0.CO;2-8.
16. Hortensteiner S, Kräutler B. Chlorophyll breakdown in higher plants. Biochim. Biophys. Acta (BBA) – Bioenerg 2011;1807:977–988. doi: org/10.1007/s000180050434.
17. Ishikawa S, Hare MC, Kettlewell PS. Effects of strobilurin fungicide programmes and fertilizer nitrogen rates on winter wheat: leaf area, dry matter yield and nitrogen yield. J Agric Sci 2012;150:427-441. doi:org/10.1017/S0021859611000724.
18. Jadoski CJ, Rodrigues JD, Soratto RP, dos Santos CM, Ribeiro E. Ação fisiológica da piraclostrobina na assimilação de CO2 e enzimas antioxidantes em plantas de feijão condicionado em diferentes tensões de água no solo. Irriga 2015;20:319. doi: org/10.15809/irriga.2015v20n2p319.
19. Jorgensen LN, Olesen JE. Fungicide treatments affect yield and moisture content of grain and straw in winter wheat. Crop Prot 2002;21:1023-1032. doi: 10.1016/S0261-2194(02)00086-8.
20. Kildea S, Dunne B, Mullins E, Cooke LR, Mercer PC. Pyraclostrobin reduces germ tube growth of QoI-resistant *Mycosphaerella graminicola* pycnidiospores and the severity of septoria tritici blotch on winter wheat. Plant Pathol 2010;59:1091–1098. doi: 10.1111/j.1365-3059.2010.02348.x.
21. Koehle H, Grossmann K, Jabs T, Stierl R, Gerhard M. Physiological Effects of the Strobilurin Fungicide F 500 on Plants Modern Fungicides and Antifungal Compounds III. Mann GmbH & Co. KG, Bonn, Germany 2002, 61-74.
22. Kozlowski LA, Simões DFM, Souza CD, Tentro M. Efeito fisiológico de estrobilurina F 500® no crescimento e rendimento do feijoeiro. Rev. Acad. Ciên. Agr. Ambient 2009;7:41-54.
23. Kumudini S, Hume DJ, Chu G. Genetic improvement in short season soybeans: I. dry matter accumulation, partitioning, and leaf area duration. Crop Sci 200;41:391-398.
24. Kyveryga PM, Blackmer TM, Mueller DS. When do foliar pyraclostrobin fungicide applications produce profitable soybean yield responses? Plant Health Progress 2013. doi: 10.1094/PHP_2013-0928-01-RS.
25. Mayee CD, Datar VV. Phytopathometry Technical Bulletin-l (Special Bulletin-3), Marathwada Agricultural University, Parbhani 1986.
26. Morrison MJ, Voldeng HD, Cober ER. Physiological changes from 58 years of genetic improvement of short-season soybean cultivars in Canada. Agron. J 1999;91:685-689.
27. Nason MA, Farrar J, Bartlett D. Strobilurin fungicides induce changes in photosynthetic gas exchange that do not improve water use efficiency of plants grown under conditions of water stress. Pest Manag. Sci 2007;63:1191-1200. doi: org/10.1002/ps.1443.
28. Poonpolgul S, Kumphai S. Chilli/Pepper anthracnose in Thailand country report. In: Oh, D.G. and Kim, K.T. (edi.) Abstract of the First International Symposium on Chilli Anthracnose. Republic of Korea: National Horticultural Research Institute, Rural Development and Administration 2007, pp. 23.
29. Ramachandran N, Madhavi RK, Rathanmma K. Current Status of Chilli Anthracnose in India. First International Symposium on Chilli Anthracnose. Hoam Faculty House, Seoul National University, Seoul, Korea 2008, pp. 26.
30. Ruske R, Gooding M, Jones S. The effects of triazole and strobilurin fungicide programmes on nitrogen uptake, partitioning, remobilization and grain N accumulation in winter wheat cultivars. J. Agric. Sci 2003;140:395-407. doi: 10.1017/S0021859603003228.
31. Santoshreddy Machenahalli, Nargund VB, Hegde RV. Management of fruit rot causing seed borne fungal pathogens in chilli. The Bioscan 2014;9(1):403-406.
32. Sarwat M, Naqvi AR, Ahmad P, Ashraf M, Akram NA. Phytohormones and microRNAs as sensors and regulators of leaf senescence: assigning macro roles to small molecules. Biotechnol. Adv 2013;31:1153-1171. doi: org/10.1016/j.
33. Shilpa R, Koppad Mesta RK, Tatagar MH. Management of fruit rot of chilli during drying using solar tunnel dryer. Int J Chem Stud 2017;5(4):2107-2109.
34. Soares LH, Fagan EB, Casaroli D, Andrade DM, Soares AL. Aplicação de diferentrs estrobilurinas na cultura da soja. Rev. FZVA 2011, 18.
35. Specht JE, Hume DJ, Kumudini SV. Soybean yield potential - A genetic and physiological perspective. Crop Sci 1999;39:1560-1570.
36. Than Haryudian Prihastuti, Sitthisack Phoulivong, Paul, WJ, Taylor. Chilli anthracnose disease caused by *Colletotrichum* species. J Zhejiang Univ Sci B 2008;9(10):764-778.
37. Venancio WS, Rodrigues MAT, Begliomini E, de Souza NL. Physiological effects of the strobilurin fungicides on plants. Publ. UEPG Ci. Exatas Terra, Ci. Agr. Eng., Ponta Grossa 2003;9:59-68.
38. Wheeler BEJ. An Introduction to Plant Diseases, John Wiley and Sons Limited, London 1969, 301.