International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2017; 5(5): 967-971

Received: 07-07-2017
Accepted: 08-08-2017

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Evaluation of Hexaconazole 4% + ZINEB 68% WP against leaf and fruit spot complex in pomegranate

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Abstract
The field experiment was conducted on Bhagawa variety of Pomegranate during Hasta Bahar of 2011-12 and 2012-13 at Vadki Village of Gangavati to evaluate Hexaconazole 4% + Zineb 68% WP against the most common and important diseases leaf and fruit spots caused by a complex association of *Alternaria alternata, Crescospora punicae* and *Colletotrichum* sp. which effects quality and market value of pomegranate fruits. The experiments were laid out in randomized block design with three replications of eight treatments. The fungicide was applied at disease initiation stage and data after three consecutive applications (at 15 days interval) was taken on the incidence leaf and fruit spot was scored as Per cent Disease Index (PDI) by following 0-9 scale. During 2011-12, treatment Hexaconazole 4% + Zineb 68% WP @ 30 g/10 L per tree basis dose recorded leaf spot incidence of 3.78 PDI and fruit spot incidence of 5.41 PDI with the yield of 11.9 t/ha followed by same fungicide @ 25 g/10 L per tree basis i.e. leaf spot of 4.46 PDI and fruit spot of 6.27 PDI at 10th day after third spray with the yield of 10.8 t/ha. Similarly, during 2012-13, same fungicide @ 30g/10L recorded leaf spot of 7.98 PDI and fruit spot of 7.27 PDI with the yield of 12.8 t/ha followed by same fungicide @ 25 g/10 L per tree basis i.e. leaf spot of 8.25 PDI and fruit spot of 8.96 at 10th day after third application with the yield of 11.9 t/ha. Results obtained from the two years clearly indicated that the spraying of Hexaconazole 4% + Zineb 68% WP @ 25 and 30 g/10L per tree basis doses were effective in control leaf and fruit spot diseases and resulting higher yield with quality fruits. The first spray should be initiated just after appearance of the disease and subsequent sprays at 15 days interval.

Keywords: hexaconazole 4% + Zineb 68% WP, leaf and fruit spot, Pomegranate

Introduction
Pomegranate (*Punica granatum* L.) is an ancient, delicious fruits consumed worldwide, gaining lot of attention of the world over, because of its high economic value and nutritional values. It is one of the important fruit crops in arid and semi-arid regions commercially important in both tropical and subtropical countries known for its drought tolerance which thrives well in dry tropical conditions with marginal soils of low fertility. The fruit is symbolic for its cool, refreshing juice and valued for its medicinal properties. Being the most adaptable subtropical fruit crop, its cultivation has increased rapidly creating its image as an important cash crop in global market. It is also ruling Indian agro economy in a short span of time by exporting the fresh fruits to Middle Eastern and European countries (Anon., 2007) [1]. Among the different states growing pomegranate, Maharashtra is the largest producer occupying 2/3rd of total area in the country followed by Karnataka, Andhra Pradesh, Gujarat and Rajasthan (Sannakki and Rajpurohit, 2015) [17]. It is cultivated intensively in northern parts of Karnataka covering different districts such as Bijapur, Bagalkot, Koppal, Chitradurga, Bellary and Raichur.

However, the crop is under threat due to number of serious diseases such as bacterial blight (*Xanthomonas axonopodis* pv.*punicae*), wilt due to *Ceratocystis fimbriata*,anthracnose (*Colletotrichum gloeosporioides*) and leaf spot and severe fruit rotting due to *Alternaria alternata*, *Cercospora* sp., *Pseudocercospora* sp., *Drechslera* sp. and *Sphaceloma* sp.etc., are more or less equally important and harmful in some orchards and also take a heavy toll on the crop (Khosla and Bhardwaj, 2013). The fruit spots not only reduce the fruit yield but also reduce market value. In the recent years, *Alternaria alternata* (Fr.) Keissler has caused severe infections among the several leaf spot and fruit spot/rotting fungi on pomegranate; that poses a

greater challenge to pomegranate cultivation. The pathogen *A. alternate* responsible for fruit rot was first reported in India by Madhukar and Reddy (1976) [13] and subsequently from USA, Mexico (Farr *et al.,* 2007) [6]. The spots on leaves are isolated, irregular to round blackish-brown and enlarge to cover large area. The affected leaves turn yellow, dry up and fall down. The spots on fruits cover large area; mostly mature fruits are attacked. The plants become more susceptible when it is under any kind of stress like drought, salinity, nutritional and environmental stress (Anon, 2009). *Alternaria* infection of pomegranate is widespread particularly in rainy season/high moisture conditions.

Leaf spot and fruit spot has been noticed in northern Karnataka including Bijapur, Bagalkot and Koppal districts with disease incidence ranging from 15-80% in almost all the pomegranate growing areas (Archana, 2012). The disease has remained hitherto unexplored but potentially dangerous and an emerging disease on pomegranate. This results in drastic reduction in the yield as well as ultimate marketability by way of severe spotting on the fruit. In view of importance of the crop and effect of fungal diseases on yield, there is need for the development of effective control methods. Primary methods of controlling leaf spot include preventing long periods of wetness on the leaf surface, cultural scouting, sanitation and development of the host plant resistance with the application of fungicides (Jambhulkar *et al.,* 2012; Kumar and Srivastava, 2013). The disease is still primarily managed by use of foliar fungicides. Regarding the management of leaf spot of pomegranate many workers had done lot of works based on the chemical control. Earlier workers reported that application of fungicides is the most effective method of *Alternaria* spot and found that Chlorothalonil, Ziram, Prochloraz, Captan, Copper oxy chloride and Hexaconazole (Rawal, 2006; Jamadar and Patil, 2007; Supe *et al.*, 2013) [16, 8, 19]. Navale *et al.* (1998) [15] found that Copper oxy chloride, Ziram, Mancozeb and Captan as the best fungicides for controlling leaf spot and fruit spots of pomegranatae in mrigbahar caused by *A. alternata, Cercospora sp., Colletotrichum gloeosporioides.* Archana and Jamadar (2014) [9] reported that fungicides were the most efficient in managing the natural infection of the leaf spot and resulted in producing the highest fruit yield compared with antioxidants as well as the alteration between them.

Most of the new generation fungicides are highly specific and single site in mode of action. Thus a novel fungicide with novel mode of action needs to be identified and evaluated under field conditions. New combi-product, which is combination of systemic and contact fungicide, belongs to other triazole and EBDC chemistry. They are broad spectrum fungicides active against wide range of diseases in many crops. The paper deals with the efficacies of different doses of fungicide formulations as foliar application against leaf and fruit spot on pomegranate. Its effect on the fruit yield and its phytotoxic actions were also evaluated.

Material and Methods

The field trial was conducted to evaluate Hexaconazole 4% + Zineb 68% WP against leaf and fruit spot disease complex in pomegranate during *Rabi* 2011-12 and *Rabi* 2012-13 at Vadaki village under the jurisdiction of Agricultural Research Station, Gangavati. All the standard agronomic practices were followed as per the Recommended Package of Practices of University. The evaluation of the test fungicide was done along with standard checks and untreated control against the incidences of leaf and fruit spot complex in pomegranate. The experimental plots were laid out in randomized block design with three replications of eight treatments. The variety Bhagawa used for the study. The test fungicide was applied as foliar spray with a knapsack sprayer. The fungicide was applied at disease initiation stage and data after three consecutive applications (at 15 days interval) was taken on the incidence of leaf spot and fruit spot diseases caused by *Alternaria alternate*, *Colletotrichum* g*loesporioides* and *Cercospora punicae* respectively. Data were recorded after different days of application. Three randomly selected plants per plot were tagged and scored on the incidence of leaf and fruit spot intensity. Pomegranate leaf and fruit spot was scored in the replicated plots using disease scoring scale as mentioned below.

Table 1: Rating scale of the leaf and fruit spot (*Alternaria* sp. *Colletotrichum* sp. and *Cercospora* sp.) disease

0	No spot on leaf and fruits
1	<5% of the leaf and fruit area showing spots
3	6-20% leaf and fruit area showing spots on the leaves
5	21-50% leaf and fruit area is showing big spots on the leaves
7	51-70% leaf and fruit area is covered with the spots and drying of leaves
9	70 % leaves and fruit tend to drying; dropping of lower leaves

Further, the scored data were converted into Per cent Disease Index (PDI) of plants using formula given by Wheeler (1969)

$$PDI = \frac{\text{Sum of numerical values}}{\text{Number of leaves observed}} X \frac{100}{\text{Maximum disease rating value}}$$

In order to record the yield, crop was harvested from the individual replicated plots and average fruit yield was recorded and expressed as q/ha. The original PDI values were suitably transformed into arcsine transformed values and subjected to statistical analysis for drawing conclusions.

Phyto-toxicity

The fungicide was sprayed at the concentration of 5.0 and 6.0 g/lit and compared with untreated check. The phytotoxicity symptoms (leaf tip/surface injury, wilting, vein clearing, necrosis, epinasty and hyponasty) were recorded (Archana, 2009) [3] at 0, 1, 3, 5, 7 and 10 days after each spray as per CIB guidelines using a rating scale of 0-10. Pomegranate fruit yield was recorded at each harvest and expressed as total fruit yield in t/ha.

Results and Discussion

Minimum disease incidence in case of leaf and fruit spot of pomegranate was observed in Hexaconazole 4% + Zineb 68% WP @ 30g/10L and 25 g/10L doses and these doses were significantly superior at all the observation days in both the season. During *Rabi* 2011-12, Hexaconazole 4% + Zineb 68% WP @ 30 g/10 L per tree basis dose exhibited 5.66, 7.00 and 7.98 PDI followed by same fungicide @ 25 g/10 L per tree basis i.e. 6.00, 7.65 and 8.25 PDI respectively at 10th day after first, 10th day after second and 10th day after third application.

These doses were at par with each other and superior than all the standard check treatments. Whereas in the case of untreated control disease incidence ranged from 10.80, 18.00 and 22.40 PDI, respectively at different observatory days (Table 2). Similar trend in case of fruit spot incidence was noticed where minimum incidence was recorded in Hexaconazole 4% + Zineb 68% WP treatments @ 30 g/10 L per tree basis exhibited 3.11, 6.11 and 7.27 PDI followed by @ 25 g/10 L per tree basis doses showed 3.67, 6.67 and 8.96 PDI, respectively were significantly superior than other treatment and at par with each other after 10 days of first, second and third application. Under untreated treatment condition diseases incidence ranged 13.52, 18.25 and 29.30 percent, respectively after 10 days of first, second and third application (Table 2).

Table 2: Efficacy Hexaconazole 4% + Zineb 68% WP against leaf spot and fruit spot diseases of pomegranate during 2011-12 (1st Season)

Treatments	Doses/10 L per tree basis		PDI at different days after application								Yield (t/ha)
			Intensity of Leaf spot				Intensity of Fruit spot				
	g or ml	g a.i	0th DAA	10 DAFA	10 DASA	10 DATA	0th DAA	10 DAFA	10 DASA	10 DATA	
Hexaconazole 4% + Zineb 68% WP	20	0.8 +13.6	4.50	6.12	8.36	9.00	3.55	3.78	7.27	12.41	10.8
Hexaconazole 4% + Zineb 68% WP	25	1.0 +17	5.66	6.00	7.65	8.25	3.00	3.67	6.67	8.96	11.9
Hexaconazole 4% + Zineb 68% WP	30	1.2 +20.4	5.45	5.66	7.00	7.98	3.24	3.11	6.11	7.27	12.8
Hexaconazole 5% EC	10	0.5	4.67	6.80	9.90	10.12	3.81	5.15	12.00	18.78	10.0
Zineb 75% WP	25	18.75	4.50	7.14	9.86	10.50	3.40	5.96	12.88	20.30	9.9
Mancozeb 75 % WP	25	18.75	5.00	8.20	10.00	11.50	3.10	6.56	13.55	22.47	9.9
Propineb 70% WP	30	21.0	4.66	8.76	9.98	11.00	4.05	6.30	14.74	22.52	10.2
Untreated – Control	--	--	4.80	10.80	18.00	22.40	4.24	13.52	18.25	29.30	7.3
CD (0.05)	--	--	0.24	0.35	0.66	0.35	0.88	1.40	1.00	3.30	1.91

Note- PDI: Percent disease index, DAA= days after application. DAFA= days after first application, DASA= days after second application, DATA= days after third application

During *Rabi* 2012-13, Hexaconazole 4% + Zineb 68% WP @ 30 g/10 L per tree basis dose exhibited 2.25, 2.55 and 3.78 PDI followed by same fungicide @ 25 g/10 L per tree basis i.e. 2.46, 2.80 and 4.46 PDI, respectively at 10th day after first, 10th day after second and 10th day after third application. These doses were at par with each other and superior than all the standard check treatments. Whereas in the case of untreated control disease incidence ranged from 9.25, 14.36, and 20.00 PDI respectively at different observatory days (Table 3). Minimum incidence of fruit spot was recorded in Hexaconazole 4% + Zineb 68% WP treatments @ 30 g/10 L per tree basis exhibited 2.78, 4.27 and 5.41 percent followed by @ 25 g/10 L per tree basis doses showed 3.00, 5.11 and 6.27 PDI, respectively were significantly superior than other treatment and at par with each other after 10 days of first, second and third application. Under untreated treatment condition diseases incidence ranged 10.31, 16.52 and 23.43 percent, respectively after 10 days of first, second and third application (Table 3).

Table 3: Efficacy Hexaconazole 4% + Zineb 68% WP against leaf spot and fruit spot diseases of pomegranate during 2012-13 (2nd Season)

Treatments	Doses/10 L per tree basis		PDI at different days after application								Yield (t/ha)
			Intensity of Leaf spot				Intensity of Fruit spot				
	g or ml	g a.i	0th DAA	10 DAFA	10 DASA	10 DATA	0th DAA	10 DAFA	10 DASA	10 DATA	
Hexaconazole 4% + Zineb 68% WP	20	0.8 +13.6	2.50	3.28	3.84	5.76	3.46	3.47	6.37	8.16	10.3
Hexaconazole 4% + Zineb 68% WP	25	1.0 +17	2.45	2.46	2.80	4.46	3.00	3.00	5.11	6.27	10.8
Hexaconazole 4% + Zineb 68% WP	30	1.2 +20.4	2.20	2.25	2.55	3.78	3.40	2.78	4.27	5.41	11.9
Hexaconazole 5% EC	10	0.5	2.75	3.25	5.24	7.75	2.98	6.15	9.00	13.63	9.2
Zineb 75% WP	25	18.75	2.50	3.76	5.50	7.38	3.54	6.06	10.18	15.33	8.8
Mancozeb 75 % WP	25	18.75	2.45	4.88	6.80	8.50	3.50	6.3	13.55	19.30	9.0
Propineb 70% WP	30	21.0	2.50	4.25	6.20	8.98	3.60	5.81	11.11	16.33	10.1
Untreated – Control	--	--	2.67	9.25	14.36	20.00	3.00	10.31	16.52	23.43	7.1
CD (0.05)	--	--	0.80	0.24	1.24	1.80	0.75	0.25	1.04	1.80	1.61

Note- PDI : Percent disease index, DAA= days after application. DAFA= days after first application, DASA= days after second application, DATA= days after third application

Among the different treatments, spraying of Hexaconazole 4% + Zineb 68% WP @ 30 g/10 L per tree basis was most effective in case of all the leaf spot as well as fruit spot diseases and statistically at par with the treatment of Hexaconazole 4% + Zineb 68% WP @ 25 g/10 L per tree basis. This is in agreement with the findings of Kumari *et al.* (2015) reported that Propiconazole (0.05%) and Carbendazim (0.05%) were highly effective providing 89.9 and 90.7 per cent and 89.5 and 90.3 per cent disease control on leaves and fruits, respectively. Spraying with Propiconazole @0.1% recorded significantly the least disease incidence (PDI 4.37%) followed by Thiophanate methyl and Hexaconazole recording 11.70 and 14.47 per cent disease index, respectively. Carbendazim showed the least efficacy with 52.43 and 23.33

per cent disease index at both the concentrations *viz*., 0.05 and 0.1 per cent, respectively (Archana and Jamadar, 2014) [5]. Jamadar and Patil (2007) [8] recorded that foliar application with Difenconazole (Score 25EC) and Prochloraz 45EC @1.0 ml/l each resulted in the management of pomegranate leaf spot and fruit spot achieving more than 74.0 to 86.7 per cent reduction of the disease, respectively over unsprayed control. Spraying of Zineb (0.2%) or Chlorothanil (0.2%) at fortnightly intervals effectively controlled leaf spot and fruit rot disease in pomegranate (Rawal, 2006) [16]. Navale *et al.* (1998) [15] found that Copper oxy chloride, Ziram, Mancozeb and Captan as the best fungicides for controlling leaf spot and fruit spots of pomegranatae in mrigbahar caused by *Alternaria alternata*, *Cercospora sp.*, *Colletotrichum gloeosporioides.* The above results lend support to the present findings.

During *Rabi* 2011-12, spraying of Hexaconazole 4% + Zineb 68% WP @ 30 g/10 L per tree basis (12.8 t/ha) and @ 25 g/10 L per tree basis (11.9 t/ha) resulted into significantly increase in yield of pomegranate whereas in case of untreated control (7.3 t/ha) pomegranate production was comparatively less. Based on the yield data cost benefit ratio of different treatments was also calculated and presented in Table 4. Similarly during *Rabi* 2012-13, spraying of Hexaconazole 4% + Zineb 68% WP @ 30 g/10 L per tree basis (11.9 t/ha) and @ 25 g/10 L per tree basis (10.8 t/ha) resulted into significantly increase in yield of pomegranate whereas in case of untreated control (7.1 t/ha) pomegranate production was comparatively less. Based on the yield data cost benefit ratio of different treatments was also calculated and presented in Table 5. The results are in agreement with findings of Ginoya and Gohel (2015) reported that two foliar applications with Tebuconazole and Trifloxystrobin @0.05 per cent at an interval of 15 days was the most effective in reducing the fruit rot intensity and increasing the fruit yield of chilli over control. Archana and Jamadar (2014) [5] reported that spraying with Propiconazole recorded significantly the highest fruit yield (36.15t/ha) followed by Thiophanate methyl (31.70), Azoxystrobin (31.31t/ha), Hexaconazole (29.65t/ha), Difenconazole (23.80t/ha) was recorded in untreated control. Jamadar and Patil (2007) [8] reported that significantly highest fruit yield and more TSS was obtained by spraying of Score 25EC @1 ml/l (9831 kg/ha; 16.2) followed by Score 0.5 ml/l. In similar investigations Suryachandraselvan *et al.* (1993) and Shamarao *et al.* (1998) reported the efficacy of Paushamycin 500 ppm+copper oxy chloride (0.2%) and Kitazin 48%EC @0.15% effectively checked the pomegranate anthracnose. Thus the results of earlier workers are also in line with the results obtained in the present investigations.

Table 4: Cost Benefit ratio of Hexaconazole 4% + Zineb 68% WP in Pomegranate during 2011-12 (1st Season)

S. No	Treatment Details	Cost of Product per L or kg	Dose g or ml/ ha	No. of spray	Cost of Application (Rs/ha)	Average Yield (q/ ha)	Total income (Rs*/ha)	Total cost of cultivation (Rs/ha)	Net Benefit (Rs/ ha)	Cost benefit Ratio
1	Hexaconazole 4% + Zineb 68% WP	650	7000	3	13650.0	108.0	540000.0	98650.0	441350.0	4.5
2	Hexaconazole 4% + Zineb 68% WP	650	8750	3	17062.5	119.0	595000.0	102062.5	492937.5	4.8
3	Hexaconazole 4% + Zineb 68% WP	650	10500	3	20475.0	128.0	640000.0	105475.0	534525.0	5.1
4	Hexaconazole 5% EC	530	3500	3	5565.0	100.0	500000.0	90565.0	409435.0	4.5
5	Zineb 75% WP	350	8750	3	9187.5	99.0	495000.0	94187.5	400812.5	4.3
6	Mancozeb 75 % WP	350	8750	3	9187.5	99.0	495000.0	94187.5	400812.5	4.3
7	Propineb 70% WP	480	10500	3	15120.0	102.0	510000.0	100120.0	409880.0	4.1
8	Untreated – Control					73.0	365000.0	85000.0	280000.0	3.3

* Value of pomegranate considered @ Rs.5000 /q

Table 5: Cost Benefit ratio of Hexaconazole 4% + Zineb 68% WP in Pomegranate during 2012-13 (2nd Season)

S. No	Treatment Details	Cost of Product per L or kg	Dose g or ml/ ha	No. of spray	Cost of Application (Rs/ha)	Average Yield (q/ ha)	Total income (Rs*/ha)	Total cost of cultivation (Rs/ha)	Net Benefit (Rs/ ha)	Cost benefit Ratio
1	Hexaconazole 4% + Zineb 68% WP	650	7000	3	13650.0	103.0	515000.0	98650.0	416350.0	4.2
2	Hexaconazole 4% + Zineb 68% WP	650	8750	3	17062.5	108.0	540000.0	102062.5	437937.5	4.3
3	Hexaconazole 4% + Zineb 68% WP	650	10500	3	20475.0	119.0	595000.0	105475.0	489525.0	4.6
4	Hexaconazole 5% EC	530	3500	3	5565.0	92.0	460000.0	90565.0	369435.0	4.1
5	Zineb 75% WP	350	8750	3	9187.5	88.0	440000.0	94187.5	345812.5	3.7
6	Mancozeb 75 % WP	350	8750	3	9187.5	90.0	450000.0	94187.5	355812.5	3.8
7	Propineb 70% WP	480	10500	3	15120.0	101.0	505000.0	100120.0	404880.0	4.0
8	Untreated – Control					71.0	355000.0	85000.0	270000.0	3.2

* Value of pomegranate considered @ Rs.5000 /q

Phyto-toxicity

No phyto-toxic symptoms like leaf injury, wilting, vein clearing, necrosis, epinasty and hyponasty or any other injury either on the foliage or fruits during 0, 1, 3, 5, 7 and 10 days after fungicide spray were recorded with Hexaconazole 4% + Zineb 68% WP at all the concentrations tested.

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