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Management of walnut anthracnose in a sustainable production system using inputs acceptable in organic agriculture

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Anthracnose is an important fungal foliar disease of walnut worldwide and in Kashmir it is the only threat of this nature to this crop so far. This study was carried out to devise a fungicidal spray module for management of walnut anthracnose such that the organic status of walnut crop is maintained. In this regard some sulphur-based fungicides, copper-based fungicides, horticultural mineral oil (HMO) and some of their suitable combinations were evaluated. In preliminary studies, sulphur 80 WP (0.3%), lime sulphur (0.3%) and copper oxychloride 50 WP (0.20%) + HMO (0.75%) supported >50 % disease inhibition up to 12th day as compared to copper oxychloride (0.20% and 0.25%), Bordeaux mixture (0.75% and 1.0%) and HMO (0.75%) wherein ≥50 % disease inhibition lasted for 6-9 days only. In subsequent studies on spray modules against this disease, alternate sprays of copper oxychloride 50 WP (0.20%) + HMO (0.75%) and Sulphur 80 WP (0.3%) post-rains was found to be the best suitable strategy for giving 65.65-67.57 % disease inhibition and the results were at par with those observed in another module wherein same chemicals were sprayed at fixed interval of 12 days. As such, Post-rains spray module is applicable when rain events are scanty while as the later one should be followed when rainy events will be relatively more frequent.

Keywords: Anthracnose, fungicides,organic agriculture, sulphur, sustainable, walnut

INTRODUCTION

Walnut (*Juglans regia* L.), a major dry fruit crop in the valley of Kashmir where it is affected by anthracnose [*Marssonina juglandis* (Lib.) Magnus] (Hassan *et al*. 2017; Shahid *et al*. 2024). From Kashmir, Shahid *et al*. (2024) recently reported its teleomorph as *Gnomonia leptostyla* (Fr.) and de Not. and cited anthracnose as a widely spread fungal disease that poses a significant threat to walnut crop in the valley. It is also known as black spot/blotch and affects black walnut (*Juglans nigra* L.) and other *Juglans* spp. besides *J. regia* throughout the world (Belisario, 2002; Belisario *et al.*2008).

Symptoms of walnut anthracnose are most commonly observed on leaves, twigs and also on fruits. Brown to black, roughly circular to circular spots appear on the leaves and in severe cases these infected leaves turn yellowish and drop off prematurely. Although this disease can be managed by use of any of the chemical fungicides, the health hazards due to chemical inputs in agriculture are reportedly alarming and need to be overcome or minimized at least while devising disease management strategies. As copper, sulphur and horticulture grade mineral oils are being allowed in organic agriculture (Anonymous, 2008; Beckerman, 2008), management of walnut anthracnose in a similar manner is also possible. Therefore, some copper and sulphur based fungicides were evaluated for their bio-efficacy against this disease so that an eco-friendly strategy is worked out for the farming community.

MATERIAL AND METHODS

The experiments on efficacy of some selected fungitoxicants against *M.juglandis* vis-à-vis effective persistence and bio-efficacy were conducted in FoA SKUAST-Kashmir at Wadura

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Sopore. For effective persistence, treatments viz. copper oxychloride 50 WP (CoC) @ 0.25 and 0.20 %, Bordeaux mixture (BM) @ 0.75 and 1.00 %, HMO @ 0.75 %, CoC + HMO @ 0.20% and 0.75%, lime sulphur @ 0.30 %, sulphur 80 WP @ 0.30 % were evaluated under polyhouse conditions (Temp. 27±2^0 C and RH >90%) in CRD with three replications.The qualifying effective persistence of a chemical would mean a minimum of 50 % disease inhibition for a minimum period of 7 days. Test concentrations of different chemicals were prepared on formulation basis and then sprayed with a baby-sprayer. After applying treatments, the pathogen was inoculated on 0, 3rd, 6th, 9th, 12th and 15th day post-treatment and persistence of a fungitoxicant was tested by recording leaf spot incidence on 14th day post-inoculation. Disease inhibition %was worked out on the primary data of spotting incidence by formula [(C-T)/C]×100, where C = No. of leaf spots in check and T = No. of leaf spots in treatment.In subsequent studies, two most effective treatments as obtained in previous experiment were evaluated in five different modules based on varying gaps between two sprays. The experiment was conducted on two-three year old grafted walnut plants under field conditions during 2021 and 2022. As such there were five modules which were evaluated in RBD with four replications and in each module, there were alternate sprays of most effective treatments for a period of two months. In present case, most effective treatments adjudged for the study were CoC (0.20%) + HMO (0.75%) and sulphur 80 WP (0.30 %). Their effective persistence period was 12 days and the details of different spray modules is given in Table1. Disease intensity on leaves were recorded while using 0-7disease scoring scale where 0 = no disease, 1 d" 20, 3 = 21-40, 5 = 41-60 and 7 > 60% diseased leaf area on the basis of visual observations. Disease intensity was calculated by using formula ["(n×v)/N×G]×100, where n = number of diseased leaves in each category, v = numerical value of the category N = total number of leaves examined, and G = highest grade value i.e., 7 in this case. Based on this data the disease inhibition over untreated check was also calculated by using formula (C-T)/C as given above.

RESULTS AND DISCUSSION

The data on efficacy of fungitoxicants against *M.juglandis* vis-à-vis effective persistence (Table-2) reveals that all the treatments were found effective initially. However, three treatments *viz*., sulphur 80 WP (0.3%), lime sulphur (0.3%), and mixture of CoC (0.20%) and HMO (0.75%) showed effective persistence period of 12 days for giving ≥50 % disease inhibition up to 12th day as compared to copper oxychloride, BM and sole HMO which showed effective persistence of 6-9 days only. Previous reports mentioning effectiveness of CoC and BM against walnut anthracnose also support the present observations (Zamani *et al*. 2011). Additionally, present research showed that the effective persistence of sulphur compounds is greater than that of copper compounds. Moreover, combined application of CoC and HMO produced a complimentary effect. This complimentary effect may be the inherent tenacity and sticky nature of HMO which consequently retained CoC on leaf surface for relatively longer time. Similar results were found by Rae *et al*. (2002). However, they have not mentioned any reasons for the enhanced persistence.

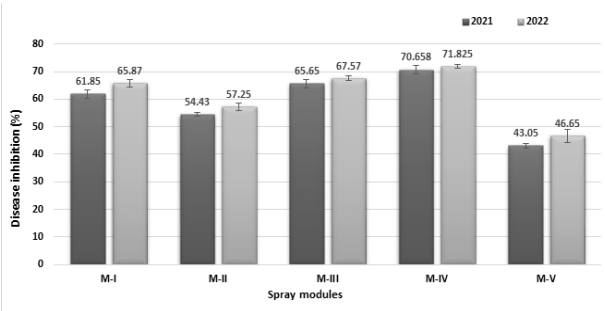

Fig.1 : Fungicide spray modules and inhibition of walnut anthracnose

Five spray modules evaluated against walnut anthracnose under open field conditions exhibited varied results which were also comparable across two seasons (Table 3 and Fig. 1). Perusal of data reveals that Module-IV significantly reduced the disease intensity to 12.68 % and inhibited the disease by 70.21 % during 2021. Module-III which inhibited disease by 65.65 % was 2nd best closely following Module-IV. Module-I which reduced the disease intensity to 16.51 % was statistically at par with Module-III. However,

Table 1. Different spray modules evaluated against walnut anthracnose

Module No.	Treatment details
I	Alternate sprays of CoC (0.20 %) + HMO (0.75 %) and sulphur 80 WP (0.30 %) at m aximum effective interval
II	Alternate sprays of CoC (0.20 %) + HMO (0.75 %) and sulphur 80 WP (0.30 %) only prior to rains but not before half of the effective persistence period (i.e., not <6 days interval in case of frequent rains)
III	Alternate sprays of CoC (0.20 %) + HMO (0.75 %) and sulphur 80 WP (0.30 %) only post rains but not before half of the effective persistence period (i.e., not <6 days interval in case of frequent rains).
IV	Alternate sprays of CoC (0.20 %) + HMO (0.75 %) and sulphur 80 WP (0.30 %) at fixed interval of 07 days
V	Alternate sprays of CoC (0.20 %) + HMO (0 .75 %) and sulphur 80 WP (0.30 %) at fixed interval of 14 days

Table 2: Efficacy of fungitoxicants against walnut anthracnosevis-à-vis effective persistence

	Leaf spot incidence for different post treatment inoculation intervals (No./leaf)					Disease inhibition for different post treatmer inoculation intervals (%)				
Fungitoxicants	3	6	9	12	15	3	6	9	12	15
CoC (0.25%)	1.26	2.53	3.80	4.45	5.36	84.08	68.16	52.26	44.00	32.66
CoC (0.20%)	1.46	2.73	3.86	4.72	5.57	81.57	65.65	49.74	40.65	30.02
BM (0.75%)	1.23	2.36	3.53	4.16	5.22	84.54	70.34	55.60	45.55	34.33
BM (1%)	1.10	2.20	3.40	4.29	5.16	86.13	72.27	57.28	47.73	36.00
HMO (0.75%)	1.80	3.20	4.50	5.50	6.30	77.02	59.79	43.46	30.90	19.59
CoC (0.20%) + HMO (0.75%)	1.04	1.93	3.06	3.93	5.04	86.84	75.35	61.47	50.58	36.59
Lime sulphur (0.3%)	0.99	1.86	2.86	3.86	4.93	87.55	75.83	63.98	51.42	38.01
Sulphur 80 WP (0.3%)	0.88	1.73	2.59	3.66	4.86	88.85	77.49	67.45	53.93	38.85
Check (only water)	7.96	-	-	-	-					
SE (m)						0.915	0.734	0.630	0.998	0.888
CD ($P \leq 0.05$)						2.276	2.219	1.930	3.019	2.684

Module-V which reduced the disease intensity to mere 24.71 % and exhibited disease inhibition of 43.66 % was found least effective. During year 2022, it was again Module-IV that produced best effect with lowest disease intensity (10.97 %) and highest disease inhibition (71.82 %). Module-III that exhibited the respective figures as 12.88 % and 67.57 % was found 2nd best. Similar effect was also exhibited by Module-I. While as minimal effect was shown by M-II with a disease inhibition of 57.25 % and least effect was shown by Module-V with a disease intensity of as much as 20.78% as compared to check where disease intensity of 38.95% was recorded. Spraying at maximum effective interval i.e., 12 days in present case offered results similar to those of post-rain application. Although 7 day's application interval produced best results, it involves high input costs and may add more fungicide residues to environment. Therefore, Module-I and Module-III are considered more suitable for management of walnut anthracnose. Spray modules have not been evaluated earlier but the efficacy of some chemicals against this disease has been reported (Hassan *et al*. 2017; Zamani *et al*. 2011). Effective results obtained with Module-I and the results of previous study on effective persistence period of these test formulations also draw support from each other. The better results obtained with post-rains application as compared to those of pre-rain application in the present investigation was possible as the rainy spells were of short duration.

Table 3. Evaluation of Copper and Sulphur based spray modules for management of walnut anthracnose.

		Disease intensity (%)			Disease inhibition over control (%)	
		Year 2021		Year 2022*	Year 2021	Year 2022
Spray Module	Initial	Final	Incremental	Incremental		
M-I	4.22	20.73	16.51	13.26	61.85	65.87
M-II	2.07	21.90	19.83	16.29	54.43	57.25
M-III	3.12	17.99	14.87	12.88	65.65	67.57
M-IV	3.20	15.88	12.68	10.97	70.21	71.82
M-V	2.00	26.71	24.71	20.78	43.66	46.65
Check	3.57	46.93	43.36	38.95	-	-
			0.661	0.567		
			2.011	1.725		

SE (m) will be under check (1st column)- and will be in same row as 0.661 . there will be no values in 2nd and 3rd columns

CD (P d" 0.05). will be below SE (m) and will be in same row as 2.011. There will be no values in the row in columns 2 and 3

*Initial disease score was Zero in all treatments

Long rainy spells would have facilitated spore germination and subsequent infection, and thus the results of these contact fungicides with post-rain application would have been poor. Moreover, it is presumed that the post-rain application of these contact fungicides effectively protected the infection court by neutralizing the germinating conidia without getting washed away as was the fate of pre-rain application.

Alternate sprays of CoC (0.20 %) + HMO (0.75 %) and Sulphur 80 WP (0.3 %) at fixed interval of 12 days will effectively inhibit walnut anthracnose in case there are frequent rains in a growing season and post-rains spraying of these chemicals is recommended for management of this diseases in case the rainy events are scanty/ widely distributed.

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DECLARATIONS

Conflict of Interest. Authors declare no conflict of interest.

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