International Journal of Bio-resource and Stress Management https://ojs.pphouse.org/index.php/IJBSM

Crossref

IJBSM March 2024, 15(3): 01-07 **Article** AR5125

Research Article *Stress Management*

DOI: HTTPS://DOI.ORG/10.23910/1.2024.5125

Evaluation of Integrated Pest Management Practices against the Incidence of White Fly and Bean Yellow Mosaic Virus (BYMV) in Rajmash (*Phaseolus vulgaris* L.)

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ABSTRACT

The present field experiment was carried out at Regional Agricultural Research Station farm, Chintapalle, Andhra Pradesh, India in three consequent years during *rabi* seasons (October-February) of 2020–21, 2021–22 and 2022–23 to evaluate the Integrated Pest Management practices to contain insect pests on rajmash (*Phaseolus vulgaris* L.). The experiment was carried out using ten treatments viz., seed treatment with imidacloprid @ 6 ml kg^{-1} seed, seed treatment intercrop with mustard (6:1), seed treatment intercrop with maize (6:1), seed treatment border crop 2 rows with maize, seed treatment yellow sticky traps @ 25 ha^{-1}, seed treatment+NSKE @ 5%, seed treatment+neem oil @ 5 ml l^{-1}, seed treatment dimethoate @ 2 ml l^{-1}, seed treatment acetamiprid @ 0. 2 g l^{-1} and untreated control (without seed treatment) replicated thrice. The pooled data revealed that all the treatments were significantly superior over check. Among the treatments, seed treatment with imidacloprid @ 6 ml kg^{-1} seed+foliar spray with acetamiprid @ 0.2 g l^{-1}) was proved effective in recording lowest mean whitefly population (5.66) with 65.06 mean per cent reduction of the whitefly population over untreated control and also resulted lowest mean incidence of bean yellow mosaic disease (5.54%) at 45 DAS. The highest net profit (₹ 6840 ha^{-1}) was obtained from the plots treated with acetamiprid followed by dimethoate. The next best treatments were rajmash+maize intercropping (6:1) and neem oil registered with the net profit of ₹ 5730, ₹ 5200 and ₹ 2275 ha^{-1}, respectively.

KEYWORDS: BYMV, evaluation, ICBR, IPM practices, rajmash, whitefly

***Citation* (VANCOUVER):** Seetharamu et al., Evaluation of Integrated Pest Management Practices against the incidence of white fly and Bean Yellow Mosaic Virus (BYMV) in Rajmash (*Phaseolus vulgaris* L.). *International Journal of Bio-resource and Stress Management,* 2024; 15(3), 01-07. HTTPS://DOI.ORG/10.23910/1.2024.5125.

Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

Conflict of interests: The authors have declared that no conflict of interest exists.

RECEIVED on 11th January 2024 RECEIVED in revised form on 29th February 2024 ACCEPTED in final form on 13th March 2024 PUBLISHED on 21st March 2024

1. INTRODUCTION

Rajmash (*Phaseolus vulgaris* L. (2n=22) belongs to family, Fabaceae. It is a traditional crop of temperate region and can be grown on wide range of soil but thrives well in well drained, loamy and light alluvial soil with pH 6.0 to 7.0 (Yang et al., 2023). In India rajmash (*Phaseolus vulgaris* L.) is largely grown in Himachal Pradesh, Jammu and Kashmir, Uttar Pradesh, North Eastern Hills, Darjeeling, South plateau Hills (Nilgiris and Palani hills) Mahabaleshwar, Ratnagiri (Maharashtra) and Chick Mangalore (Karnataka) (Nirmala et al., 2015 and Naik et al., 2022). Rajmash as a legume vegetable plays a major role in nourishment of human population due to high protein content (21.1%) and plays a strategic role against protein calorie malnutrition and reducing the risk of chronic disease in India in developing countries (Heerden and Schonfeldt, 2004, Kumar et al., 2006, Raju and Mehta, 2009, Shivanand et al., 2023 and Kimani et al., 2023). The dry rajmash beans have potential health benefits for humans because of their anti-oxidant, anti-diabetic, anti-obesity, anti-inflammatory and good for bladder burns, diarrhoea, eczema and hiccups reported by (Ganesan and Xu, 2017; Abhishek et al., 2021). In Andhra Pradesh rajmash is a traditional pulse crop in the tribal areas of erstwhile Visakhapatnam district and has more social and economic significance than other legume vegetable crops. It is grown in shoddy and undulated lands in late kharif (02nd Fortnight of August - 01st Fortnight of September) and rabi (October - February), seasons in an area of 9800 ha with a productivity of 350 kg ha^{-1} (Ashoka et al., 2021, Naik et al., 2022). The rajmash is susceptible to both biotic and abiotic stresses, of which the damage caused by insect pests and disease are the major constraints to the low productivity of the rajmash, particularly in the tropics and the yield losses due to insect pests alone have been estimated to the tune of 35% to 100% annually (Graham and Vance, 2003, Singh and Schwartz, 2011, Naik et al., 2022, Shivanand et al., 2023).

Rajmash is attacked by a vast array of insect pests such as, flea beetles, leaf miner, stem fly, bean weevil, aphids, white fly, thrips; defoliators and spider mites under open field conditions and are causing considerable economic damage as reported by several workers from various regions of India (Srivastava and Agarwal, 2004, Sharma et al., 2005, Abrol et al., 2006, Sadhu et al., 2008, Singh and Schwartz, 2011, Oyewale and Bamaiyi, 2013, Singh, 2013, Noor et al., 2014, Singh and Singh, 2015, Kalita et al., 2016, Amit et al., 2017, Mondal et al., 2018, Naik et al., 2022 , Wajid et al., 2022, Shivanand et al., 2023). (Njau and Lyimo 2000, and Naik et al., 2022) reported that the crop is mainly attacked by viral diseases viz., Bean Yellow Mosaic Virus (BYMV), Bean Seed Borne Mosaic Virus and bean common mosaic virus (BCMV). Rajmash cultivated in the high altitude and tribal zone is severely affected by the incidence of various insect pests viz., whitefly, aphids and flea beetle and a deadly disease Bean Yellow Mosaic Virus (BYMV). Whitefly *Bemesia tabaci* Gen. directly causing damage to the crop and indirectly involved in transmission of Bean Yellow Mosaic Virus (BYMV)are the major constraints in impeding the yields. In the recent years, pest management strategies have receiving greater attention across the globe for their utilization as ecofriendly and sustainable approach. In light of this background, the present experiment was conducted to evaluate the effective Integrated Pest Management strategies against insect pests and bean yellow mosaic viral disease on rajmash.

2. MATERIALS AND METHODS

2.1. Study area, design, lay out and details of experiment

The present investigation was carried out in three consequent years i.e., from *Rabi* (October – February) of 2020–21, 2021–22 and 2022–2023 at ANGRAU, Regional Agricultural Research Station, Chintapalle, Visakhapatnam district, located in the eastern ghats region, Andhra Pradesh, India which lies between 17º-34' 11" and 18º-32' 57" northern latitude and 18º-51' 49" and 83º-16' 9" in eastern longitude. It is bounded on the north partly by Odisha state and partly by Vizianagaram district, on south by East Godavari district, on west by Odisha state and east by Bay of Bengal. The experiment was carried out to evaluate the effective integrated pest management practices against whiteflies and bean yellow mosaic disease on rajmash in sandy clay loamy soil in field number 4 of the research farm and laid out in simple randomized block design (RBD) using a popularly growing cultivar of rajmash Chintapalli red (Ctpl-red) with ten treatments including one untreated check, replicated thrice with a plot size of 5×4 m^2 and a spacing of 30×10 cm^2. Inter cultivation operations like thinning and gap filling were taken 15 days after sowing and other agronomic practices were adopted as per the university recommended package of practices. The details of IPM practices were seed treatment with imidacloprid @ 6 ml kg^{-1} seed, seed treatment intercrop with mustard (6:1), seed treatment intercrop with maize (6:1), seed treatment+border crop 2 rows with maize, seed treatment + yellow sticky traps @ 25 ha^{-1}, seed treatment+NSKE @ 5%, seed treatment+neem oil@ 5 ml l^{-1}, seed treatment+ dimethoate @ 2 ml l^{-1}, seed treatment+acetamiprid@ 0. 2 g l^{-1} and untreated control (without seed treatment) for testing their efficacy against the whiteflies and to contain the disease incidence of BYMV on rajmash,

2.2. Methodology and data collection

To impose the treatments seed treatment was done one day before sowing with Imidacloprid (6 ml kg^{-1} seed)

and the treatments of intercrops and border crop with maize and mustard, respectively were sown along with the rajamsh as per the recommended ratio (6:1). The insecticidal treatments were imposed first on 45 days after sowing. The application of foliar spray treatments measured quantity of insecticide was mixed in small quantity of water and later made up with water to required volume of spray fluid; each plot received 0.6 L of spray fluid 500 l ha^{-1}. The spray fluid was thoroughly stirred before spraying. Sprayings were given by using a knapsack high volume sprayer. The plot in each treatment was sprayed with respective insecticides ensuring uniform coverage of insecticide. The sprayer and the accessories were thoroughly washed before changing the insecticides and also rinsed with the spray fluid of the chemical to be applied next.

The observations of the whitefly population were recorded one day prior to spraying as pre-treatment count and 3rd, 7th and 14th day after spraying as post-treatment counts. The data on incidence of whiteflies were collected from the top middle and bottom trifoliate leaves per plant from 10 randomly selected plants of each plot and per cent disease incidence of BYMV was recorded from whole plot from the whole plot at 30 days after sowing and finally before harvest. The per cent population reduction in different treatments was calculated by modified Abbot's formula (Flemming and Ratnakaran, 1985) and the data were subjected to ANOVA and the data was transformed to the corresponding square root values. (Gomez and Gomez, 1984) (Table 1).

Table 1: Details of the treatments

Treatments	Details
T_1	Seed treatment with imidacloprid @ 6 ml kg^{-1} seed
T_2	Seed treatment+intercrop with mustard 6:1
T_3	Seed treatment+intercrop with maize 6:1
T_4	Seed treatment+border crop 2 rows with maize
T_5	Seed treatment+yellow sticky traps @25 ha^{-1}
T_6	Seed treatment+NSKE @ 5%
T_7	Seed treatment +neem oil @ 5 ml l^{-1}
T_8	Seed treatment+dimethoate @ 2 ml l^{-1}
T_9	Seed treatment+acetamiprid @ 0.2G l^{-1}
T_{10}	Untreated control (without seed treatment)

Percent population reduction=1-(Post treatment population in treatment/ Pre treatment population in treatment)×(Pre-treatment population in untreated control)×100

Per cent BYMV Incidence=(No. of plants infected in a row/ Total no. of plants in a row)×100

The yield data of marketable seeds in each treatment were recorded separately and subjected to statistical analysis to test the significance of mean yield in different treatments. The percentage increase in yield over control in each treatment was calculated by using the following formula.

Per cent increase of yield over control=(Yield in treatment -Yield in control)/Yield in control)×100

Cost benefit ratio = Cost of increased yield (₹ ha^{-1})/Cost of treatment (₹ ha^{-1})

3. RESULTS AND DISCUSSION

3.1. Evaluation of IPM practices against whitefly and bean yellow mosaic virus disease on rajmash

On scrutiny of the pooled results of the experiment conducted in three consequent years *ie.*, from *Rabi* (October- February) 2020–21, 2021–22 and 2022–23 on the evaluation of different IPM practices for the management of whiteflies and yellow mosaic disease on rajmash revealed that all the treatments were significantly superior over each other in managing the incidence of whitefly and YMV. The overall mean efficacy of post treatment observations were recorded at 3rd, 7th and 14 DAS indicated that all the treatments were significantly superior over untreated check. The overall mean per cent reduction of the whitefly population has ranged from 19.63–65.06. Among all the treatments in three consequent years the treatment T9 (Seed treatment with imidacloprid+foliar spray with acetamiprid @ 0.2 g l^{-1}) was proved effective and recorded lowest mean whitefly population (5.66) with 65.06 mean per cent reduction of the whitefly population over untreated control and lowest mean incidence of bean yellow mosaic disease (5.54%) at 45 DAS this might be due to the dual effect of the seed treatment with Imidacloprid contained the insect pests at initial stages of the crop growth and later stages the foliar application of acetamiprid due to its novel systemic insecticidal activity and detrimental effect on the whitefly population; followed by T_8 (Seed treatment+ foliar spray with Dimethoate @ 2 ml l^{-1}) these two treatments were on par with each other; out of the intercrop with maize the treatment T_3 (seed treatment+Intercrop with maize 6:1) had showed significant in reduction of the incidence of whitefly population and in turn reduced the bean yellow mosaic incidence this might be due to the maize inter crop harshly barricade the movement of the vector whitefly and companion and neighbouring plants could reduce pest pressure by providing habitat for the pest's enemies and the results are presented in table 2.

The results of the present investigation seed treatment with Imidacloprid+ foliar spray with acetamiprid @ 0.2 g l^{-1} was found very effective against the incidence of whitefly and BYMV disease this might be due to the systemic effect of imidacloprid and translaminar action of acetamiprid on the insect vector at initial and later stages might be the

Table 2: Pooled Effect of treatments on the incidence of whitefly and YMV disease in rajmash *rabi*, 2020–21 to 2022–2023

Treatments	Mean white fly population per 3 leaves plant^{-1}							
	Pre treatment	Post treatment					Over all mean YMV (%)	Yield (q ha^{-1})
		2020-21	2021-22	2022-23	Over Allmean	Mean per cent reduction over control		
T_1	10.33	9.89 (3.28)*	7.55 (3.01)*	10.22 (3.30)*	9.22 (3.19)^{bc*}	46.11	17.84 (4.34)*	1.16
T_2	9.57	9.89 (3.28)	13.55 (3.74)	14.77 (3.94)	12.74 (3.69)^{cd}	19.63	21.71 (4.76)	0.91
T_3	10.44	7 (2.81)	10.44 (3.29)	10.33 (3.36)	9.26 (3.19)^{bc}	46.45	11.37 (3.51)	1.44
T_4	9.78	7.66 (2.92)	12.55 (3.56)	11.89 (3.56)	10.70 (3.40)^{bc}	33.95	17.49 (4.28)	1.01
T_5	10.56	10.45 (3.38)	10.89 (3.34)	16.44 (4.15)	12.59 (3.67)^{cd}	28.02	18.47 (4.37)	1.04
T_6	10.55	7.22 (2.84)	11.78 (3.52)	11.44 (3.51)	10.15 (3.32)^{bc}	26.15	17.94 (4.35)	1.19
T_7	9.45	8.89 (3.12)	10.89 (3.41)	14.89 (3.95)	11.56 (3.53)^{cd}	41.92	15.04 (3.99)	1.27
T_8	10.67	5.89 (2.61)	8.11 (2.98)	10.78 (3.41)	8.26 (3.02)^{b}	49.01	8.37 (3.05)	1.72
T_9	9.78	5.33 (2.50)	4.33 (2.22)	7.33 (2.85)	5.66 (2.57)^{a}	65.06	5.54 (2.55)	1.86
T_{10}	11.00	16.22 (4.34)	15.78 (4.06)	22.67 (4.85)	18.22 (4.37)^{e}	--	29.25 (5.49)	0.42
Ftest	NS	Sig.	Sig.	Sig.	Sig.		Sig.	sig
SEm±		0.10	0.18	0.14	0.13		0.22	0.31
CD (*p*=0.05)		0.30	0.53	0.43	0.39		0.66	0.93

*values in parenthesis are square root transformed values

reason for low disease incidence the results are in promise with the findings of (Wang et al., 2009, Amit et al., 2017, Jain et al., 2022) who had reported that the seed treatment with Imidacloprid 600 FS @ 5 ml kg^{-1}, first foliar spray of Diafenthuron 50 WP @ 0.1% and second foliar spray with Acetamiprid 20SP @ 0.5 g l^{-1} at 30 and 45 DAS respectively++yellow sticky trap has resulted significantly less YMD incidence and the minimum mean whitefly population and highest seed yield of black gram; Acetamiprid 4%+fipronil 4% @ 2 ml l^{-1} was recorded 64.92 mean per cent reduction in whitefly population over untreated control and 18.26% YMV incidence over untreated control on blackgram at North coastal Andhra Pradesh (Seetharamu et al., 2020). The whitefly acted as a vector in transmission of the bean yellow mosaic virus disease on rajmash are in corroboration with the findings of (Chailani et al., 1994, Njau and Lyimo, 2000, Tolkach and Gnutova, 2001) who had reported that the whitefly (*Bemesia tabaci* G,) involved in transmission of Bean Yellow Mosaic Virus (BYMV) and observed that the leaves were showed mosaic, vein banding and downward curling of leaves in french bean (*Phaseolus vulgare* Linn.) The next best treatments were T8 dimethoate foliar spray and) T_3 rajmash intercrop with maize were found effective against the whitefly and BYMV on rajmash are in agreement with the findings of Wajid et al., 2022 who had reported that soil application with carbofuran 3G @ 32.5 kg ha^{-1}+first spray with dimethoate 30 EC @ 0.03% (45 DAS) and 2nd spray with dichlorvos 76 SC @ 0.076% (70 DAS) maximum reduction of whitefly (71.74% and 79.11% at 45 DAS and 70 DAS, respectively) was observed in rajmash/common bean intercrop with maize at Jammu and Kasmir. The treatments that are in descending order of efficacy were T_7 Seed treatment+Neem oil @ 5 ml l^{-1}; T_1 Seed treatment with Imidacloprid @ 6 ml kg^{-1} and T_6 Seed treatment+NSKE@5% which were on par with each other and recorded with 49.1, 46.45 and 46.11 mean per cent reduction of whitefly population respectively, over untreated control. These findings were in accordance with the results of (Ambarish et al., 2022) who had reported that the lowest whitefly population (1.70 trifoliate leaf^{-1}) and significantly lowest MYMV incidence was recorded in greengram with maize as a border crop+one spray of NSKE 5% at 20 days after sowing+one spray of fish oil rosin soap @ 5 ml l^{-1} at 40 DAS. The efficacy of NSKE results is in tune with the findings of Malik et al., 2021 and reported that application of 5 per cent NSKE at the flowering stage amplified the insecticides efficiency and reduced the population of whitefly and aphids in greengram. The highest population reduction of FAW egg masses and larval population was recorded in NSKE @ 5% (71.43 and 60.87%, respectively in sorghum (Sunitha et al., 2023). The efficacy of Seed treatment with imidacloprid and spraying

with neem oil was effective against sucking pests in rajmash the results are in conformity with the findings of Shivanand et al., 2023 who had reported that azadirachtin 3000 PPM @ 5 ml l^{-1} (11.53±0.43 no. five leaf $^{-1}$) with 62.96 per cent reduction of aphids on french bean at Uttara Kannada. To combat the sucking insect pests and yellow mosaic disease on various pulse crops are in harmony with the findings of (Roth et al., 2016, Sharmah and Rahman, 2017, Wajid et al., 2022, Mim et al., 2023).

3.2. Yield and incremental cost benefit ratio

The data pertaining to seed yield revealed that increased yield varied from 49.0 kg ha^{-1}–144.0 kg ha^{-1} in different treatments when compared with untreated control in the present investigation. Maximum seed yield of 186.0 kg ha^{-1} was recorded with the treatment T_9 (Seed treatment with imidacloprid+foliar spray with acetamiprid @ 0.2 g l^{-1}) followed by seed treatment+Dimethoate @ 2 ml l^{-1}, seed treatment with imidacloprid++maize (intercropping 6:1) and seed treatment with imidacloprid+ Neem oil @ 5 ml l^{-1} with grain yield of 172.0, 144.0 and 127.0 kg ha^{-1}, respectively. However, minimum grain yield of 42.0 kg ha^{-1} was recorded in untreated control. The highest net profit (₹ 6840 ha^{-1}) was obtained in plots treated with acetamiprid followed by dimethoate, Rajmash+maize (intercropping) and neem oil with the net profit of 5730, 5200 and 2275 ₹ ha^{-1}, respectively. The results of seed treatment and maize as intercrop and border crop has reduced the incidence of whitefly and BYMV might be due to the maize is a tall-growing plant and acts as a barrier crop that helped to prevent the movement of small insect pests from one field to another these findings are in corroboration with Wajid et al., 2022 who had reported that maximum reduction of pests (76.85, 75.43, 69.97% of aphid, whitefly and weevil, respectively) and resulted in maximum gross returns (₹ 94,068), net returns (₹ 64,017) and benefit cost ratio (2.13) in French bean. Ambarish et al., 2022 who has reported that border crop of African tall maize+seed treatment with imidacloprid 70 WS+reflective mulch+spraying of triazophos 40 EC at 0.175% at 30 days after sowing+ spraying with thiamethoxam 25 WDG at 0.05% at 45 DAS had recorded the lowest whitefly population, yellow mosaic virus incidence and highest yield in pole bean and greengram. similar results are in conformity with (Rizvi and Singh, 1994, Kaniuczak and Matosz, 1998, Kasina et al., 2006) who had reported that imidacloprid foliar spray and intercropping with maize has considerable potential in IPM programs on french bean. The lowest net profit (₹ 150 ha^{-1}) was estimated from the treatment of T_2 (Seed treatment with Imidacloprid+Mustard (intercropping). By working out the cost benefit ratio, it has revealed that T_9 (Seed treatment with imidacloprid+foliar spray acetamiprid @ 0.2 g l^{-1}) with highest cost benefit ratio of 1.73 followed by Dimethoate, Rajmash+maize (intercropping) seed treatment imidacloprid and neem oil with 1.43, 1.42, 0.66 and 0.55 C:B ratio, respectively the results were presented in table 3. The findings of these investigations were in agreement with the findings of (Ambarish et al., 2022, Wajid et al., 2022) who had reported that 2.13 C:B ratio with seed treatment+foliar spray with acetamiprid and dimethoate in common bean.

Table 3: Economics of the IPM practices evaluated on Rajmash *rabi*, 2020–21 to 2022–2023

Treatments	Input cos ₹ ha^{-1}	Labour cost ₹ ha^{-1}	Total cost ₹ ha^{-1}	Yield kg ha^{-1}	Increase in yield over control kg ha^{-1}	Value of yield ₹ ha^{-1} @ 75 kg^{-1}	Net profit ₹ ha^{-1}	ICBR	Rank
T_1	670	2800	3470	116.0	74.0	5625.0	2155	0.62	4
T_2	725	2800	3525	91.0	49.0	3675.0	150	0.04	9
T_3	850	2800	3650	144.0	102.0	7650.0	4000+1200* =5200	1.42	3
T_4	850	2800	3650	101.0	59.0	4425.0	775+600* = 1375	0.38	6
T_5	795	2800	3595	104.0	62.0	4650.0	1055	0.29	8
T_6	1020	3200	4220	119.0	77.0	5775.0	1555	0.37	7
T_7	900	3200	4100	127.0	85.0	6375.0	2275	0.55	5
T_8	820	3200	4020	172.0	130.0	9750.0	5730	1.43	2
T_9	760	3200	3960	186.0	144.0	10800.0	6840	1.73	1
T_{10}	-			42.0	-	-	--	--	10

*Maize fresh cobs @ ₹ 10 cob^{-1}

4. CONCLUSION

Seed treatment with imidacloprid @ 6 ml kg^{-1} seed+foliar spray with acetamiprid @ 0.2 g l^{-1}) was very effective and recorded lowest mean whitefly population (5.66), highest (65.06%) population reduction over untreated control and also resulted lowest incidence of bean yellow mosaic disease (5.54%) and resulted highest net profit (₹ 6840 ha^{-1}).

5. ACKNOWLEDGEMENT

The first author is highly thankful to Acharya N. G. Ranga Agricultural University Lam, Guntur, Andhra Pradesh and Associate Director of Research, Regional Agricultural Research Station, Chintapalle for providing the facilities to carry out the present study.

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