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BIO-EFFICACY OF NEWER MOLECULES OF INSECTICIDES AGAINST BRINJAL SHOOT AND FRUIT BORER, *Leucinodes orbonalis* GUENEE (LEPIDOPTERA : PYRALIDAE)

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ABSTRACT

A field experiment was carried out in a randomized block design with 12 treatments (eleven insecticides and one control) and 3 replications during *kharif* 2010 at College Agronomy Farm, Bansilal Amritlal College of Agriculture, Anand Agricultural University, Anand to evaluate newer molecules of insecticides for their bio-efficacy against brinjal shoot and fruit borer, *Leucinodes orbonalis* Guenee (Lepidoptera : Pyralidae) in brinjal (*Solanum melongena* Linnaeus) crop. The order of effectiveness was emamectin benzoate (Proclaim 5 WG) 0.0025% (89.56) > flubendiamide (Fame 480 SC) 0.01% (83.70) > rynaxypyr (Coragen 20 SC) 0.006% (81.04) > lufenuron (Match 5 EC) 0.005% (74.62) > novaluron (Remon 10 EC) 0.01% (69.03) > indoxacarb (Fego 15.5 SC) 0.007% (67.46) > thiodicarb (Larvin 75 WP) 0.075 (61.66) > spinosad (Spintor 45 SC) 0.0135% (59.55) > endosulfan (Thiodan 35 EC) 0.07% (52 32) > dichlorvos (Nuvan 76 EC) 0.076% (45.97) > fenvalerate (Tatafen 20 EC) 0.01% (36.63) based on per cent reduction in shoot damage; emamectin benzoate (75.06) > flubendiamide (63.02) > rynaxypyr (61.55) > lufenuron (49.93) > novaluron (47.69) > indoxacarb (45.34) > thiodicarb (41.08) > endosulfan (39.98) > spinosad (37.27) > dichlorvos (25.58) > fenvalerate (24.51) based on per cent reduction in fruit damage; emamectin benzoate (151.41) > flubendiamide (123.46) > novaluron (110.07) > rynaxypyr

(107.81) > spinosad (106.66) > thiodicarb (96.67) > indoxacarb (95.51) > lufenuron (88.85) > endosulfan (75.38) > dichlorvos (70.46) > fenvalerate (67.56) based on per cent increase in fruit yield; and dichlorvos (1:19.27) > endosulfan (1:15.26) > fenvalerate (1:13.42) > indoxacarb (1:8.42) > thiodicarb (1:7.70) > emamectin benzoate (1:6.92) > flubendiamide (1:6.10) rynaxypyr (1:5.56) > spinosad (1:5.49) > novaluron (1:5.33) > lufenuron (1:5.25) based on net incremental cost: benefit ratio. Novaluron and fenvalerate were found to be "moderately harmful", while rest of the insecticides were "harmless" to predatory spiders in brinjal crop.

KEY WORDS**:** *Leucinodes orbonalis,* brinjal, newer insecticides, spiders

INTRODUCTION

Brinjal (*Solanum melongena* Linnaeus) also known as eggplant is referred a "King of vegetables", originated from India and now grown as a vegetable throughout the tropical, sub-tropical and warm temperate areas of the world. The production of brinjal is about 3,20,72,972 metric tones (MT) in the world and India is world's second largest producer of brinjal after China (Anonymous, 2008a). In India, the crop is grown in about 5, 66,100 hectares and produces 95, 96, 100 MT. The West Bengal, Orissa, Bihar and Gujarat are the major producing states of the country with the highest productivity of 27, 35,000 MT in West Bengal. In Gujarat, the total area under brinjal is 55,800 hectares with annual production of 9, 88, 140 MT (Anonymous, 2008b). Patel *et al.* (1970) recorded 16 pest species attacking the brinjal crop in Gujarat, of which brinjal shoot and fruit borer (BSFB), *Leucinodes orbonalis* Guenee (Lepidoptera : Pyralidae) is one of the major pests. Early larval instars of BSFB feed exclusively on flower buds, flowers and shoots. While, later instars larva bore into fruits reducing their marketable value and in extreme cases, making the fruits unfit for human consumption. Due to poor natural enemy complex, concealed nature of the pest and successive cropping, this pest remains active throughout the year. The crop loss caused by this pest varies from 37 to 63 per cent in different parts of India (Dhankhar, 1988) and from 15-70% in most of all brinjal producing areas of the world (Sandanayake and

Edirisinghe, 1992). It is estimated that the economic injury level equals to 6% infestation of shoot and fruit in India (Alam *et al.*, 2003).

Farmers of Asian countries in most cases solely depend on insecticides for the management of the pest. Such reliance on insecticides has created many problems such as very frequent application of insecticides (up to 140 times in a season), excessive residues on market vegetables that concerns general consumer health and the environment, pesticide resistance, trade implications, poisoning, hazards to non-target organisms, increased production costs etc. (Alam *et al.*, 2003). Among the several avenues to overcome the insecticidal resistance problem, replacement with new molecules of insecticide is one of the important considerations. Evaluation of newer molecules for their efficacy against *L. orbonalis* is also a continuous process as newer molecules having novel mode of action are introduced in the market. Considering above facts, the present investigation was carried on evaluation of newer molecules of insecticides for their bio-efficacy against BSFB.

MATERIALS AND METHODS

A field experiment was laid out during *kharif* 2010 at College Agronomy Farm, Bansilal Amritlal College of Agriculture, Anand Agricultural University, Anand in a randomized block design with 12 treatments (Table 1) and 3 replications each having plot size of 6.0 x 3.6 m. Brinjal variety GOB-1 was transplanted at a spacing of 90 x 60 cm on 15th July, 2010. Two spray application of respective insecticide, first at appearance of shoot damage and second at fruit initiation were made on the using manually operated hydraulic knapsack sprayer with a pressure of 3.5 kg/ cm^2 to the extent of slight run-off from the plant.

The observations on number of healthy and damage shoots were made on 5 randomly selected plants in each treatment replication-wise 7, 14 and 21 days after first spray. In similar way, observations number of healthy and damage fruits were also made. Based on these observations, percentages of damaged shoots and fruits were worked out and subjected to ANOVA after transforming them to arcsine. The data on shoot and fruit damage were also pooled over 3 weekly observations. To see the toxic impact of different insecticides on naturally occurring predatory spiders in brinjal agroecosystem, the observations on numbers of spiders were recorded on the three randomly selected plants in each replication under different treatments 7, 14 and 21 days after first and second spray. The data on spider population were subjected to ANOVA after transforming them to root. The data on spider population were also pooled over periods and sprays. The per cent reduction in shoot and fruit damage as well as spider population over control was worked out treatment-wise using the formula: [(% damage in control – % damage in treatment) ÷ (% damage in control] x 100. The toxicity of different insecticidal to predatory spiders was adjudged based on per cent over control *i.e.*, Harmless: <25% reduction; slightly harmful: 25-50 % reduction; moderately harmful: 51-75% reduction; and Harmful: > 75% reduction (Hassan *et al*., 1985). The fruit yield in each plot was weighed separately at each picking. A total of eight pickings were made and data on fruit yield was summed up replication-wise for each treatment and subjected to ANOVA. The per cent increase in yield was worked out treatment-wise by using the formula: [(yield in treatment – yield in control) ÷ (yield in control] x 100.

The incremental cost benefit ratio (ICBR) was also worked out for different insecticidal treatments. For the purpose, total cost of plant protection was worked out on the basis of cost of insecticidal formulation used and labour charges for their application. Gross income of brinjal fruits was worked out on the basis of prevailing market price for each treatment. Gross realization was worked out by deducting the cost of plant protection from the gross income. Net realization over control was calculated by deducting the gross realization of control from gross realization of each treatment. Net profit of a treatment was calculated by deducting total cost of treatment from net realization over control. Gross ICBR for each treatment was calculated dividing net realization over control by total cost of plant protection. Finally, net ICBR (NICBR) for each treatment was calculated by deducting one from the gross ICBR.

RESULTS AND DISCUSSION

Impact on damage to shoots:

The data on shoot damage pooled over periods (Column 2 in Table 1) revealed that all insecticides treatments recorded significantly lower damage (1.53 to 9.29%) than control (14.66%). The chronological order of insecticides based on per cent shoot damage and reduction over control (given in bracket after each treatment, respectively) in comparison to control was: emamectin benzoate 0.0025% (1.53 & 89.56) > flubendiamide 0.01% (2.39 & 83.70) > rynaxypyr 0,006% (2.78 & 81.04) > lufenuron 0.005% (3.72 & 74.62) > novaluron 0.01% (4.54 & 69.03) > indoxacarb 0.007% (4.77 & 67.46) > thiodicarb 0.075 (5.62 & 61.66) > spinosad 0.0135% (5.93 & 59.55) > endosulfan 0.07% (6.99 & 52 32) > dichlorvos 0.076% (7.92 & 45.97) > fenvalerate 0.01% (9.29 & 36.63) > control (14.66). Emamectin benzoate, the most effective insecticide was at par with flubendiamide but significantly superior to rest of the insecticides. Flubendiamide was at par with rynaxypyr which was in turn at par with lufenuron. Novaluron and indoxacarb were at par with each other as well as with lufenuron on one side and with thiodicarb and spinosad on other side of the chronological order. Fenvalerate, the least effective insecticide was at par with dichlorvos, which was in turn at par with endosulfan. Overall, emamectin benzoate, flubendiamide and rynaxypyr recording more than 80% reduction in over control were found most effective insecticides in preventing damage to shoots by BSFB.

Impact on damage to fruits:

The data on fruit damage pooled over periods (Column 3 in Table 1) indicated that all insecticidal treatments recorded significantly lower per cent fruit damage (7.66 to 23.19) than control (30.72). The chronological order of insecticides based on per cent fruit damage and reduction over control (given in bracket after each treatment, respectively) in comparison to control was: emamectin benzoate 0.0025% (7.66 & 75.06) > flubendiamide 0.01% (11.36 & 63.02) > rynaxypyr 0.006% (11.81 & 61.55) > lufenuron 0.005% (15.38 & 49.93) > novaluron 0.01% (16.07 & 47.69) >

indoxacarb 0.007% (16.79 & 45.34) > thiodicarb 0.075 (18.10 & 41.08) > endosulfan 0.07% (18.56 & 39.98) > spinosad 0.0135% (19.27 & 37.27) > dichlorvos 0.076% (22.86 & 25.58) > fenvalerate 0.01% (23.19 & 24.51) > control (30.72). Emamectin benzoate was found significantly superior to other insecticides. Flubendiamide and rynaxypyr, the next effective insecticides, were significantly to rest of the insecticides. Lufenuron, novaluron, indoxacarb, thiodicarb and endosulfan were on par with each other. Fenvalerate was at par with dichlorvos, which was at par with spinosad. Overall, emamectin benzoate, flubendiamide and rynaxypyr recording more than 70% reduction in over control were found most effective insecticides in preventing damage to fruits by BSFB.

Impact on predatory spiders:

The data on population of predatory spiders pooled over periods and sprays (Column 4 in Table 1) revealed that the difference among the treatments was significant. The chronological order of insecticides based spiders population per plant and percent reduction over control (given in bracket after each treatment, respectively) in comparison to control was: control (1.06) > endosulfan (0.92 & 13.21) > spinosad (0.87 & 17.92) > emamectin benzoate (0.85 & 19.81 > rynaxypyr (0.75 & 29.24) > flubendiamide (0.73 & 31.13) > thiodicarb (0.56 & 47.17) > indoxacarb (0.48 & 54.72) > lufenuron (0.44 & 66.04) > dichlorvos (0.42 & 60.38) > novaluron (0.36 & 66.04) > fenvalerate (0.33 & 68.87). Endosulfan, spinosad, emamectin benzoate, rynaxypyr and flubendiamide were statistically at par with control. Thiodicarb, indoxacarb, lufenuron, dichlorvos, novaluron and fenvalerate recorded significant lower spiders' population than control. Novaluron and fenvalerate reduced the spider's population over control by more than 25 per cent but less than 50 per cent and can be categorized as "moderately harmful"; while rest of the insecticides did not reduce more than 25 per cent population of spiders over control and can be categorized as "harmless" to spiders in brinjal crop.

Impact on fruit yield:

The effectiveness of insecticides was also reflected on fruit yield. The data on fruit yield (Column 2 in Table 1) revealed that all insecticides recorded significantly higher fruit yield (23.14 to 34.72 quintals /ha) than control (13.81 quintals /ha). The chronological order of different insecticides based on yield (quintals /ha) and per cent increase over control (given in bracket after each treatment, respectively) in comparison to control was: emamectin benzoate (34.72 & 151.41) > flubendiamide (30.86 & 123.46) > novaluron (29.01 & 110.07) > rynaxypyr (28.70 & 107.81) > spinosad (28.54 & 106.66) > thiodicarb (27.16 & 96.67) > indoxacarb (27.00 & 95.51) > lufenuron (26.08 & 88.85) > endosulfan (24.22 & 75.38) > dichlorvos (23.54 & 70.46) > fenvalerate (23.14 & 67.56) > control (13.81). All the insecticides except emamectin benzoate were at par with each other. However, emamectin benzoate was at par with flubendiamide, novaluron, rynaxypyr, spinosad, thiodicarb and indoxacarb. Thus, emamectin benzoate, flubendiamide, rynaxypyr spinosad and spinosad recorded more than double yield of marketable fruits and can considered as effective insecticides against BSFB so far fruit yield is concerned.

Economics:

The details on economics of various insecticides are presented in Table 2. The chronological order of insecticides based on net profit (Rupees /ha) was emamectin benzoate (27,405) > flubendiamide (21,975), novaluron (19,200), rynaxypyr (18,935), spinosad (18,695), thiodicarb (17,725), indoxacarb (17,685), lufenuron (15,868), endosulfan (14,655), dichlorvos (13,875) and fenvalerate (13,025). Based on NICBR, the chronological order was: dichlorvos (1:19.27) > endosulfan (1:15.26) > fenvalerate (1:13.42) > indoxacarb (1:8.42) > thiodicarb (1:7.70) > emamectin benzoate (1:6.92) > flubendiamide (1:6.10) rynaxypyr (1:5.56) > spinosad (1:5.49) > novaluron (1:5.33) > lufenuron (1:5.25). In spite of lower effectiveness, yield and net profit, dichlorvos, endosulfan and fenvalerate recorded higher NICBR because of lower price of these insecticides. While, emamectin benzoate, flubendiamide and rynaxypyr recorded comparatively lower NICBR in spite of their higher effectiveness, yield and net profit, because of very high price of these insecticides.

Various insecticides are evaluated against BSFB by different researchers during last 10 years and reported variable results. Six sprays of endosulfan 700 g a. i. /ha at 15 days interval from 30 days after transplanting was effective resulting into minimum shoot and fruit damage by BSFB (Sharma and Chhibber, 1999). Borad et al. (2002) recorded the higher marketable fruit yield and minimum infestation when brinjal crop was sprayed with mixture of endosulfan 35 EC and cypermethrin 5 EC @ 2.50 l/ha. Endosulfan 0.07% recorded lower fruit infestation of BSFB and higher ICBR (Bhatt, 2003). Endosulfan + fenvalerate (0.07% + 0.005%) and dichlorvos + fenvalerate (14.9%) were found effective in reducing damage by BSFB to fruits, increasing fruit yield and recording higher cost - benefit ratio (Abrol and Singh, 2003). Novaluron 37.5 g a. i. /ha harvested maximum marketable fruit yield followed by thiodicarb @ 375 g a. i. /ha due to effective control of BSFB (Chatterjee and Roy, 2004). Thiodicarb at 0.75 kg a. i/ha recorded the lowest shoot and fruit damage by BSFB (Sahu *et al.*, 2004). Lower damage to fruits is recorded due to application of endosulfan 0.07% on brinjal (Eswara Reddy and Srinivasa, 2005). According to Tohnishi et al. (2005), flubendiamide is having extremely strong insecticidal activity against lepidopteran insect pests and also very safe to non target organisms. Emamectin benzoate @ 200 g / ha, reduced fruit borer infestation and recorded higher fruit yield of brinjal (Prasad Kumar and Devappa, 2006). Spinosad 0.01% and thiodicarb 0.1% were found effective in reducing shoot and fruit borer infestation and increasing yield (Deshmukh and Bhamare, 2006). Emamectin benzoate 0.001 and spinosad 0.0045 recorded lowest shoot and fruit infestation and highest marketable fruit yield brinjal (Jyoti, 2006). Novaluron recorded higher suppression of the growth rate of BSFB (Patnaik *et al.*, 2007). Flubendiamide showed the highest toxicity against fourth instar larvae BSFB in laboratory and reduced more than 80% shoot and fruit infestation in field conditions (Latif *et al.*, 2007). New molecule a-endosulfan 35 % EC another isomer of commercial endosulfan 35 % EC was found effective at

2.0 ml/litre to curb the menace of brinjal shoot and fruit borer and to harvest better fruit yield of brinjal (Sreenivas et al., 2007). Spinosad 0.015% individually and its combination with novaluron was found most effective in reducing shoot infestation besides recording higher fruit yield of brinjal (Naik *et al.*, 2008). Flubendiamide 500 g /ha resulted into minimum shoot and fruit damage with higher fruit yield (Biswas *et al.*, 2009). Flubendiamide @ 90 and 72 g a.i./ha was significantly superior in reducing the shoot and fruit damage and recorded higher fruit yields of brinjal (Jagginavar *et al*., 2009). Application of flubendiamide 0.012% applied at 5% level of shoot and fruit infestation in addition to of mechanical control + potash @ 100 kg/ha + field sanitation reduced the fruit infestation and recorded higher fruit yield as well as benefit-cost ratio (Latif *et at*., 2009a). Considering number of sprays, marketable yield of brinjal and also BCR; 5% fruit infestation was considered as economic threshold of flubendiamide spraying for the management of BSFB (Latif *et al.*, 2009b). Indoxacarb at 75 and 150 g a.i. /h was effective in reducing fruit infestation by BSFB (Jayakrishnan and Madhuban, 2009). Spinosad 50 g a. i. /ha followed by indoxacarb 50 g a. i. /h, emamectin benzoate 15 g a. i. /h and lufenuron 50 g a. i. /ha recorded lower shoot and fruit infestation and highest marketable fruit yield of brinjal (Patra *et al*., 2009). Emamectin benzoate 0.002% followed by endosulfan 0.05% and novaluron 0.0024% were more effective as compared to spinosad in preventing damage to shoot, endosulfan recorded higher cost benefit ratio, while emamectin benzoate followed by endosulfan and spinosad 0.0024% were more effective as compared to novaluron in preventing damage to shoot damage by BSFB (Anil and Sharma, 2010). Endosulfan 0.07% was found effective in reducing shoot and fruit borer and increasing fruit yield of brinjal (Wargantiwar *et al*., 2010). Dichlorvos at 0.03%, 0.02% and 0.01% was found to be more effective than endosulfan at same concentration in reducing fruit borer damage and increasing the fruit yield of brinjal (Chand *et al*., 2011).

CONCLUSION

Over all, it can be concluded that emamectin benzoate at 0.0025%, flubendiamide at 0.01%, rynaxypyr at 0.006%, lufenuron at 0.005% and novaluron at 0.01% recorded comparatively lower shoot and fruit damage and higher fruit yield and were found promising insecticides for the management of BSFB.

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Table 1. Impact of different insecticidal treatments evaluated for the control of shoot and fruit borer, *L. orbonalis* on different parameters in brinjal

Treatments	Parameters			
	% damaged shoots (Pooled over 3 weekly observations after 1st spray)	% damaged fruits (Pooled over 3 weekly observations after 2nd spray)	Population of predatory spiders /plant (Pooled over 3 periods and 2 sprays)	Fruit yield (Q. /ha)
Emamectin benzoate 0.0025 % (Proclaim 5 WG)	7.11a (1.53) [89.56]	16.07a (7.66) [75.06]	1.16abc (0.85) [19.81]	34.72a [151.41]
Thiodicarb 0.075 % (Larvin 75 WP)	13.71ef (5.62) [61.66]	25.18cd (18.10) [41.08]	1.03bcde (0.56) [47.17]	27.16ab [96.67]
Indoxacarb 0.007 % (Fego 15.5 SC)	12.61de (4.77) [67.46]	24.19cd (16.79) [45.34]	0.99cde (0.48) [54.72]	27.00ab [95.51]
Spinosad 0.0135 % (Spintor 45 SC)	14..10ef (5.93) [59.55]	26.04de (19.27) [37.27]	1.17ab (0.87) [17.92]	28.54ab [106.66]
Novaluron 0.01 % (Remon 10 EC)	12.30de (4.54) [69.03]	23.63cd (16.07) [47.69]	0.93e (0.36) [66.03]	29.01ab [110.07]
Lufenuron 0.005 % (Match 5 EC)	11.12cd (3.72) [74.62]	23.09c (15.38) [49.93]	0.97de (0.44) [66.04]	26.08b [88.85]
Flubendiamide 0.01 % (Fame 480 SC)	8.89ab (2.39) [83.70]	19.70b (11.36) [63.02]	1.11abcd (0.73) [31.13]	30.86ab [123.46]
Rynaxypyr 0.006 % (Coragen 20 SC)	9.60bc (2.78) [81.04]	20.10b (11.81) [61.55]	1.12abcd (0.75) [29.24]	28.70ab [107.82]
Endosulfan 0.07 % (Thiodan 35 EC)	15.33fg (6.99) [52.32]	25.52cd (18.56) [39.98]	1.19ab (0.92) [13.21]	24.22b [75.38]
Dichlorvos 0.076 % (Nuvan 76 EC)	16.34gh (7.92) [45.97]	28.56ef (22.86) [25.58]	0.96de (0.42) [60.38]	23.54b [70.46]
Fenvalerate 0.01 % (Tatafen 20 EC)	17.75h (9.29) [36.63]	28.79f (23.19) [24.51]	0.91e (0.33) [68.87]	23.14b [67.56]
Control (water spray)	22.51i (14.66)	33.66g (30.72)	1.25a (1.06)	13.81c
S. Em. ±	0.68	0.95	0.06	2.63
C. D. at 5 %	1.92	2.65	0.17	7.72
C. V. %	14.56	12.12	24.53	17.28

Note: *Figures in parentheses ( ) are retransformed values, those outside are arcsine value in column 2, 3 and 4; Figures in parentheses [ ] are % decrease over control in column 1, 2 and 3, while % increase in column 4; Treatment means with letter(s) in common are not significant at 5 % level of significance within a column.*

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Table 2. Economics of various insecticides evaluated for their field bioefficacy against *L. orbonalis*

Treatments	Quantity of insecticides for two sprays	Cost of insecticide (₹ /l or kg)	Cost of labour (₹/ha)	Total cost of plant protection for two sprays (₹ /ha)	Yield (q /ha)	Gross realization (₹ /ha)	Net realization over control (₹/ha)	Net profit (₹ /ha)	ICBR	NICBR
Emamectin benzoate 0.0025 %	0.5 kg	7119	400	3960	34.72	52,080	31,365	27,405	1:7.92	1:6.92
Thiodicarb 0.075 %	1.0 kg	1900	400	2300	27.16	40,740	20,025	17,725	1:8.70	1:7.70
Indoxacarb 0.007 %	0.5 litre	3400	400	2100	27.00	40,500	19,785	17,685	1:9.42	1:8.42
Spinosad 0.0135 %	0.3 litre	10000	400	3400	28.54	42,810	22,095	18,695	1:6.49	1:5.49
Novaluron 0.01 %	1.0 litre	3200	400	3600	29.01	43,515	22,800	19,200	1:6.33	1:5.33
Lufenuron 0.005 %	1.0 litre	2137	400	2537	26.08	39,120	18,405	15,868	1:6.25	1:5.25
Flubendiamide 0.01 %	0.2 litre	16000	400	3600	30.86	46,290	25,575	21,975	1:7.10	1:6.10
Rynaxypyr 0.006 %	0.3 litre	10000	400	3400	28.70	43,050	22,335	18,935	1:6.56	1:5.56
Endosulfan 0.07 %	2.0 litres	280	400	960	24.22	36,330	15,615	14,655	1:16.26	1:15.26
Dichlorvos 0.076 %	1.0 litre	320	400	720	23.54	35,310	14,595	13,875	1:20.27	1:19.27
Fenvalerate 0.01 %	1.0 litre	570	400	970	23.14	34,710	13,995	13,025	1:14.42	1:13.42
Control (Water spray)	-	-	-	-	13.81	20,715	-	-	-	-

Market price of fruit yield: *₹ 1500 /quintal;* ***Labour charges:*** *For spraying: ₹ 100/labour/day two labours per hectare required for one spray)*