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Integration of Seed Dressing, Bio-pesticides and Intercropping to Reduce Pesticide Use in Snap Bean Production

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Abstract: Insect pests remain a major constratint in the production of snap beans and farmers mainly rely on synthetic chemical pesticides to manage the insect pests and diseases. However, the introduction of maximum residue levels (MRLs) for export vegetables by European markets pose a challenge to the use of pesticides. This study developed sustainable options of managing snap bean pests and reducing chemical residues on snap bean produce. Field experiments were carried out for two planting cycles and evaluated the efficacy of seed dressing, sprays with neem, pyrethrin or biological product and intercropping with maize either alone or in combination. The data collected included population of whitefly, thrips and bean fly; yield and pest damage. The use of seed dressing in combination with two pyrethrin sprays and neem applied at the vegetative stage, early flowering and early pod growth stage reduced bean stem maggot, white fly and thrips population by up to 71%. This was comparable to the use of seed dressing combined with intercropping with maize plus three pyrethrin sprays at the vegetative stage, early flowering and early pod growth stage. The two options also reduced pod damage due to thrips by up to 87% and increased yield by up to 189%. The results demonstrated that integrated pest management options would be viable alternatives to synthetic chemical pesticides and this would enable snap bean farmers produce within acceptable residue limits.

Keywords: Bio-Pesticides, Chemical Residues, Integrated Pest Management, Intercropping, Market Access, *Phaseolus vulgaris* L, Seed Dressing

1. Introduction

Snap bean (*Phaseolus vulgaris* L.) is grown specifically for the immature green pods primarily for export market to European Union and elite local urban markets [1]. The production of snap bean, one of Kenya's most important export vegetable crops, is steadily rising [2]. Snap beans from Kenya are exported to United Kingdom, France, Holland, Germany, United Arab Emirates and South Africa [2]. Domestic consumption of snap beans has also increased over the last few years, [2]. Snap bean production is mainly by small scale farmers with over 50,000 smallholder families being involved in snap bean production in Kenya and contributing to the larger agricultural sector [1] [3].

Production of snap beans in Kenya is constrained by insect pests and diseases [4]. Insect pests cause both direct damage during feeding and indirect damage through transmission of viruses. The most important pests in snap bean production include thrips, whiteflies, bean stem maggot and aphids which cause considerable yield losses.

The most common pest management strategy in snap bean production is the use of chemical pesticides [4]. These include Confidor (Imidacloprid), Thunder (Imidacloprid 100g/L + Betacyfluthrin 45g/L), and Karate (Lambda Cyhalothrin 25g/Kg) [4] [5]. Most farmers use the chemical pesticides on calender spray regimes [4] resulting in improper and excessive use of chemical pesticides which has negative impact on enevironment, non-target organisms and leave chemical residues on the fresh produce [6] [7]. In addition, resistance to chemical insecticides by pests such as whiteflies and thrips has been reported [8] [9]. In the recent past, the European Union (EU) which is the major snap bean market has enforced stringent food safety and quality measures which have impacted negatively on market access by small scale fresh vegetable farmers in developing countries [10]. One of the measures is with regards to maximum residue levels (MRLs) which has been changed from 0.2 to 0.02 parts per million [5]. The achievement of the set MRLs is a challenge to the use of synthetic pesticides and their over reliance has often led to non compliance by Kenyan exporters resulting in in losses to farmers [11] [5].

The use pest control technologies such as reduced pesticide application frequency, use of seed dressers, bio-pesticides and modification of cropping systems is a major step towards sustainable pest management [4]. Biopesticides as effective as synthethic chemical pesticides and can be used to as an alternative to chemical pesticides in an integrated pest management system [12] [13] [14]. Botanical biopesticides include products based on plant extracts such as neem while microbial biopesticides include products based on micro-organisms such as *Verticillium lecanii* and *Bacillus subtilis* [15] [16] [17]. Seed dressing is effective for the management of sucking insect pests [18] [19] and it entails treating seeds with a systemic insecticide before sowing [18]. Intercropping reduces insect pests through increasing of the biodiversity in the ecosystem which leads to a build up of natural enemies that contribute to the management of pests [20] [21] [22]. This study was undertaken to determine the effectiveness of integrating seed dressing, foliar sprays and intercropping in the management of snap bean pests.

2. Materials and Methods

2.1. Description of the Experimental Sites

On-farm experiments were conducted in Mwea and Embu in Kirinyaga and Embu counties, respectively. The Mwea experimental site is in lower midland zone 4 (LM4), a semiarid area with nitosols soils [23]. Average rainfall is about 850 mm with a range of 500 - 1250 mm which is distributed between long rains in March to June with an average of 450 mm and short rains in Mid-October to December with an average of 350 mm. Temperatures range from 15.6°C to 28.6°C with a mean of about 22°C. Embu experimental site falls in Upper Midland 2 (UM2) agro-ecological zone [23]. The annual average maximum and minimum temperatures are 28.8°C and 9.6°C, respectively with an average annual precipitation of 1206 mm.

The production of snap beans in both sites is mainly for export and is carried out by small scale farmers organized into self-help groups within the irrigation scheme.

2.2. Description of Pest Management Products

Seed dressing was carried out using moncerene while the spray applications was by use of Nimbecidine (Azadirachtin 0.03%), Pesthrin (Pyrethrins 6%), Biocatch WP (*Verticillium lecanii*), Thunder (Imidacloprid 100 g/L + Betacyfluthrin 45g/L) and Karate (Lambda Cyhalothrin 25 g/kg) (Table 1). Alternate application of Thunder and Karate 17.5 EC comprised the farmer practice.

2.3. Experimental Layout and Design

The experiments were carried out in a farmer's field under irrigated agriculture over two cropping cycles. Snap bean variety Serengeti was planted in single rows at a spacing of 10 cm x 30 cm in 5 m x 4 m plots with 1m alleys between the plots. Ten treatment combinations were evaluated as follows:

i). Seed dressing Moncerene (Imidacloprid 233g/L +Pencycuron 50g/L +Thiram 107g/L) only; no other insect pest management practices;

ii). Farmers practice. Application of Thunder (Imidacloprid 100g/L + Betacyfluthrin 45g/L) and Karate (Lambda Cyhalothrin 25g/Kg) on pest detection;

iii). Seed dressing with Moncerene (Imidacloprid 233g/L +Pencycuron 50g/L +Thiram 107g/L) followed by three Neem (Azadirachtin 0.03%) (Nimbecidine- Azadirachtin 0.03%) sprays at vegetative stage, beginning of flowering and early podding;

iv). Seed dressing with Moncerene (Imidacloprid 233g/L +Pencycuron 50g/L +Thiram 107g/L) followed by two pyrethrin sprays using Pesthrin 6% EC (Pyrethrins 6%) at vegetative stage and beginning of flowering and a Neem (Azadirachtin 0.03%) spray (Nimbecidine- Azadirachtin 0.03%) at early podding;

v). Seed dressing with Moncerene (Imidacloprid 233g/L +Pencycuron 50g/L +Thiram 107g/L) and the snap beans planted as intercropped with maize (Baby corn); three prythroid sprays using Pesthrin 6% EC (Pyrethrins 6%) at vegetative stage, beginning of flowering and at early podding;

vi). Seed dressing with Moncerene (Imidacloprid 233g/L +Pencycuron 50g/L +Thiram 107g/L) followed by two pyrethrin sprays using Pesthrin 6% EC (Pyrethrins 6%) at vegetative stage and at beginning of flowering; one biological spray Biocatch 1.15WP (*Verticillium lecanii*) at early podding;

vii). Seed dressing with Moncerene (Imidacloprid 233g/L+Pencycuron 50g/L +Thiram Ten7g/L) followed by two Neem (Azadirachtin 0.03%) (Nimbecidine- Azadirachtin 0.03%) sprays at the vegetative stage and at beginning of flowering; one a biological spray with Biocatch 1.15WP (*Verticillium lecanii*);

viii). No seed dressing; two pyrethrin sprays using Pesthrin 6% EC (Pyrethrins 6%) at vegetative and at beginning of flowering followed by one Neem (Azadirachtin 0.03%) (Nimbecidine- Azadirachtin 0.03%) spray at early podding;

ix). Control (-ve) - no treatment at all but sprayed with water only during application of other treatments.

Table 1. *Pest management products evaluated.*

Product	Active Ingredient	Application rate
Moncerene	Imidacloprid 233g/L + Pencycuron 50g/L +Thiram 107g/L	3g ml per kg of seed
Nimbecidine	Azadirachtin 0.03%	3ml per litre of water
Pesthrin 6% EC	Pyrethrins 6%	5m per Litre of water
Biocatch 1.15WP	*Verticillium lecanii*	4kg per ha
Thunder	Imidacloprid 100 g/L + Betacyfluthrin 45g/L	10 ml in 20 litres of water
Karate	Lambda Cyhalothrin 25 g/kg	6.5 ml in 20 litres of water

Each treatment was replicated four times. Maize in the intercrop treatment was planted at the same time with the snap beans at a spacing of 75 cm by 25 cm. The experiment was laid out in a randomized complete block design (RCBD) with 1.5 m alleys between the blocks. Fertilizer application was done once at planting using diammonium phosphate (18%N and 46% P_2O_5) at the rate of 490 kg per ha and applied just before seed placement. Top dressing was done at 21 days after emergence with calcium ammonium nitrate at the rate of 490 kg per Ha. The first weeding was done two WAE followed by a second weeding two weeks later. Diseases were controlled using Kocide (Copper Hydroxide 61.4%) against rust and rots, Osothane (Mancozeb) against leaf spots and Ortiva (Azoxystrobin 250g/L) against mildews.

2.4. Assessment of Pest Population

Pests assessed were whiteflies (*Bemisia tabaci*), thrips (*Frankliniella occidentalis)* and bean stem maggot (*Ophiomyia phaseoli*). The population of whiteflies was assessed by use of yellow sticky trap counts and leaf counts [24] [25]. A yellow sticky trap was placed at the centre of each plot and the number of adult whiteflies traped on each yellow sticky trap was counted at two, four, six and eight weeks after emergence (WAE). Population of whitefly nyphs was determined by sampling ten lower leaves from ten plants in a zig-zag manner from inner rows of each plot [26] at two, four, six and eight WAE.

Population of thrips was assessed every week from the start of flowering by sampling ten flowers from ten plants per plot from the inner rows at six, seven and eight WAE. The flowers were plucked and immediately put into vials containing 70% ethanol to immobilize the insects. The number of thrips was determined by placing the flowers and ethanol in a petri dish, dissecting each flower and counting the thrips under a dissecting microscope using a tally counter [4].

2.5. Assessment of Snap Bean Pod Yield and Quality

Immature pods were harvested twice every week for two weeks from three inner rows in each plot. The harvested pods were separated into marketable and non-marketable grades. The marketable pods were further graded into extra-fine (6-7.5 mm diameter and 8-12 cm long) and fine (6.5-9 mm diameter and 10-13 cm long) according to USAID-KHCP, [27]. The non-marketable pods were also further graded into pest damaged pods and other rejects based on pest damage symptoms such as feeding marks, scarring and malformation [23].

2.6. Calculation of Cost Benefit Analysis of Experimental Treatments

The cost-benefit ratio for each treatment was calculated as follows:

Total marketable = Total extra-fine + Total fine

Average price = (Price for extra-fine + Price for fine)/2

Total cost = Land preparation cost + Labour + Cost of inputs

Gross returns = Total marketable x Average price

Net returns = Gross returns – Total cost

Cost-benefit ratio = Total cost/ Net returns

2.7. Statistical Data Analysis

Analysis of variance (ANOVA) was carried out on the data from the two seasons using GenStat Edition 13 software and tested for significance using F-test at 95% level of significance. The treatment means were then compared using the least significant difference (LSD) test at P=0.05 where the F-test was significant [28]

3. Results

The integration of seed dressing with Moncerene® (Imidacloprid 233g/L +Pencycuron 50g/L +Thiram 107g/L), three Pesthrin® (Pyrethrins 6%) foliar sprays and intercropping with maize and the integration of Moncerene® seed dressing, two Pesthrin® sprays followed by a Neem (Azadirachtin 0.03%) spray significantly ($P < 0.05$) reduced both adult and nymph whitefly population (Figure 1; Table 2). Similar results were observed for the number of thrips per flower (Table 3) and bean stem maggots per plant (Figure 2). The two most effective pest management options reduced adult whitefly population by up to 38%, the nymphs by 52% and thrips population by up to 71% compared to snap bean plots without any pest management. The farmer practice consisted of application of Thunder (Imidacloprid 100g/L + Betacyfluthrin 45g/L) and Karate (Lambda Cyhalothrin 25g/Kg) was the least effective. These results were consistent over the two cropping cycles and over the two field trial sites. Seed dressing significantly ($P<0.05$) reduced he bean stem maggots population by 27 to 57% in planting one (Figure 2). Combination of seed dressing, intercropping with maize and three pyrethrin sprays at vegetative, early flowering and early podding stage had the highest reduction of bean stem maggot by 57% (Figure 2). Similarly, combining seed dressing, pesthrin spray at the vegetative stage and early flowering followed by a neem pray at early podding reduced bean stem maggot by 55%.

Table 2. *Number of nymps and adult whitefly on snap bean crop subjected to different management options over two growing seasons.*

Management option	Adult whitefly			Whitefly nymphs		
	S1	S2	Mean	S 1	S 2	Mean
Seed dressing only (Moncerene)	113.4d	71.2c	92.3c	47.5c	39.3bc	43.2c
Farmer practice (Thunder + Karate)	89.2bc	46.5ab	67.8b	39.0b	27.4ab	33.2b
Seed dressing + 3 Neem	74.8ab	61.0bc	67.9b	37.1b	31.8bc	34.4b
Seed dressing + 2 Pesthrin + 1 Neem	59.5a	37.0a	48.2a	21.8a	22.2ab	21.8a
Seed dressing + Intercrop + 3 Pesthrin	64.3a	36.4a	50.2a	22.2a	21.2a	21.6a
Seed dressing+ 2 Pesthrin + 1 Biocatch	74.5ab	57.9bc	66.2b	39.1b	27.6ab	33.4b
Seed dressing + 2 Neem + 1 Biocatch	91.1bc	48.4ab	69.5b	40.8b	32.8bc	36.8b
2 Pesthrin+ 1 Neem	63.6a	41.2ab	51.8a	20.5a	22.3ab	21.4a
Control (Water only)	-	78.7cd	78.7b	-	45.9cd	45.9c
LSD ($_{p\leq0.05}$)	18.3	16	13.5	5.1	9.6	6.3
C.V%	5.6	5.2	1.8	6.1	9.3	7.1

Treatments with different letters in the same column are significantly different at 5% probability
Moncerene= Imidacloprid 233g/L +Pencycuron 50g/L +Thiram 107g/L; Thunder= Imidacloprid 100g/L + Betacyfluthrin 45g/L; Karate= Lambda Cyhalothrin 25g/Kg; Pesthrin= Pyrethrins 6%; Biocatch= *Verticillium lecanii;* Neem = Azadirachtin 0.03%; S1 = season 1; S2 = season 2.

Table 3. *Number of thrips per flower from snap bean crop after application of different management options at two sites.*

Management option	Mwea			Embu		
	S 1	S 2	Mean	S 1	S 2	Mean
Seed dressing only (Moncerene)	3.0d	3.7d	3.4c	0.49bc	3.0bc	1.7b
Farmer practice (Thunder + Karate)	2.4c	2.6bc	2.5b	0.34ab	1.9ab	1.1ab
Seed dressing + 3 Neem	2.0bc	2.3ab	2.1b	0.46bc	2.5bc	1.5b
Seed dressing + 2 Pesthrin + 1 Neem	1.2a	2.0ab	1.6a	0.24ab	1.8a	1.0a
Seed dressing + Intercrop + 3 Pesthrin	1.2a	1.8a	1.5a	0.20a	1.7a	1.0a
Seed dressing+ 2 Pesthrin + 1 Biocatch	1.2a	2.4ab	2.3b	0.38bc	2.2ab	1.3ab
Seed dressing + 2 Neem + 1 Biocatch	2.2c	2.4ab	2.3b	0.47bc	2.0ab	1.3ab
2 Pesthrin+ 1 Neem	1.5ab	2.1ab	1.8ab	0.23a	1.8a	1.0a
Control (Water only)	-	4.4d	4.4d	-	3.5cd	3.5c
LSD ($_{p\leq0.05}$)	0.5	0.7	0.5	0.17	0.70	0.45
C.V%	12.8	2.4	6.9	14.50	8.60	7.60

Treatments with different letters in the same column are significantly different at 5% probability
Moncerene= Imidacloprid 233g/L +Pencycuron 50g/L +Thiram 107g/L; Thunder= Imidacloprid 100g/L + Betacyfluthrin 45g/L; Karate= Lambda Cyhalothrin 25g/Kg; Pesthrin= Pyrethrins 6%; Biocatch= *Verticillium lecanii;* Neem = Azadirachtin 0.03%; S1 = season 1; S2 = season 2.

Table 4. *Total yield (Kg/ Ha) of marketable extra fine and fine grade pods harvested from snap bean crop subjected to different pest management options in Mwea and Embu field trial sites.*

Management option	Extra fine pods			Fine pods		
	S 1	S 2	Mean	S 1	S 2	Mean
Mwea						
Seed dressing only (Moncerene)	1851a	4511ab	3181a	2392a	2106ab	2249a
Farmer practice (Thunder + Karate)	4029bc	4344ab	4186ab	5551bc	1877ab	3714b
Seed dressing + 3 Neem	3885bc	4523ab	4204ab	5949bc	2059ab	4004b
Seed dressing + 2 Pesthrin + 1 Neem	4770c	6731bc	5751b	5574bc	2925bc	4250b
Seed dressing + Intercrop + 3 Pesthrin	4866c	5758bc	5312b	5879bc	2595bc	4237b
Seed dressing+ 2 Pesthrin + 1 Biocatch	2340ab	5220b	3780ab	3543ab	1777ab	2660ab
Seed dressing + 2 Neem + 1 Biocatch	2818ab	3627a	3222a	5687bc	2412b	4049b
2 Pesthrin+ 1 Neem	4178bc	5319b	4748b	6161cd	2585bc	4373b
Control (Water only)		3282a	3282ab	-	1629a	1629a
LSD ($_{p\leq0.05}$)	1461	1553	1122	2491	679	1202
C.V%	20	21.9	18.4	27.7	6.2	18.7
Embu						
Seed dressing only (Moncerene)	3378a	3060c	3219bc	3853a	2455a	3154b
Farmer practice (Thunder + Karate)	2905a	2250b	2578b	4665a	2019a	3342bc
Seed dressing + 3 Neem	3200a	2884bc	3042bc	5415a	2032a	3724bc
Seed dressing + 2 Pesthrin + 1 Neem	3654a	3905de	3780c	4429a	2498a	3463bc
Seed dressing + Intercrop + 3 Pesthrin	3581a	3746cd	3664c	4994a	2141a	3568bc
Seed dressing+ 2 Pesthrin + 1 Biocatch	3787a	2258b	3023bc	5880a	2392a	4136c
Seed dressing + 2 Neem + 1 Biocatch	2782a	3113c	2947bc	4438a	1866a	3795c
2 Pesthrin+ 1 Neem	2141a	3198c	3170bc	3789a	3251a	3520bc

Management option	Extra fine pods			Fine pods		
	S 1	S 2	Mean	S 1	S 2	Mean
Control (Water only)		1568a	1567a		1236a	1236a
LSD ($_{p\leq0.05}$)	1353	652	759	2032	1086	602
C.V%	11.3	9.2	6.6	18.9	12	13.7

Treatments with different letters in the same column are significantly different at 5% probability
Moncerene= Imidacloprid 233g/L +Pencycuron 50g/L +Thiram 107g/L; Thunder= Imidacloprid 100g/L + Betacyfluthrin 45g/L; Karate= Lambda Cyhalothrin 25g/Kg; Pesthrin= Pyrethrins 6%; Biocatch= *Verticillium lecanii;* Neem = Azadirachtin 0.03%; S1 = season 1; S2 = season 2.

Snap bean plots where pest management consisted of Moncerene seed dressing combined with Neem and Pyrethrin foliar sprays and intercropping with maize had significant (P <0.05) pod yield for both fine and extra fine pods in both experimental sites (Table 4). Dressing the snap bean seeds with Moncerene at planting and intercropping with maize combined with application of pyrethrin spray at vegetative stage and at early flowering followed by a Neem spray at early podding resulted in the highest extra-fine yield yield (Table 4). The observed increase in the extra fine pod yield was up to 81%. In the case of fine pod grade, the highest yield was obtained from plots where there was application of two pyrethrin sprays at the vegetative stage and early flowering followed by a Neem spray at early podding and also from plots where snap bean seeds were dressed with Moncerene before planting followed by two pyrethrin sprays at the vegetative stage and early flowering and a Neem spray at early podding (Table 4).

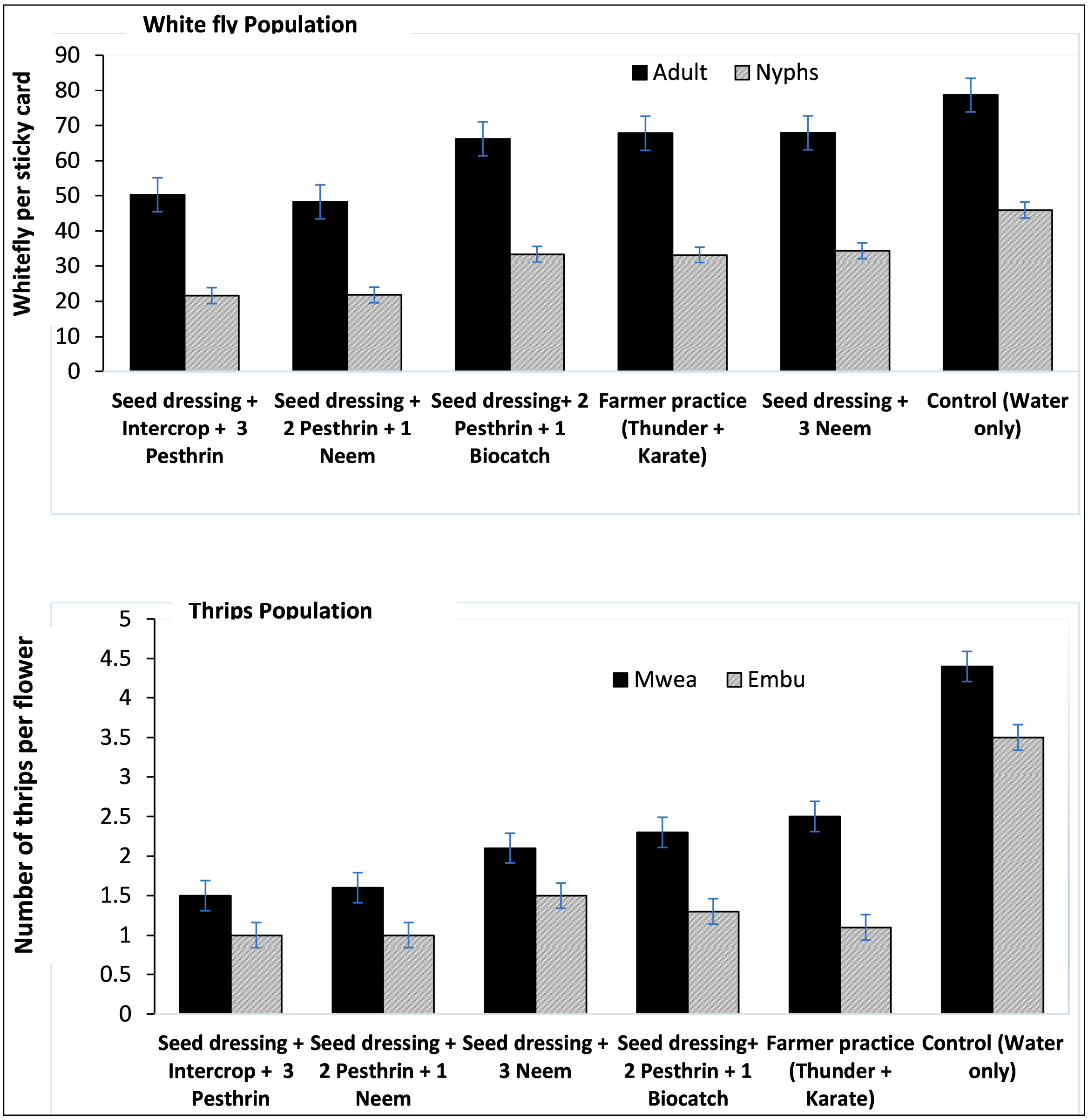

Figure 1. *Population of whitefly and thrips on snap bean crop after application of different management options at two sites, Mwea and Embu.*

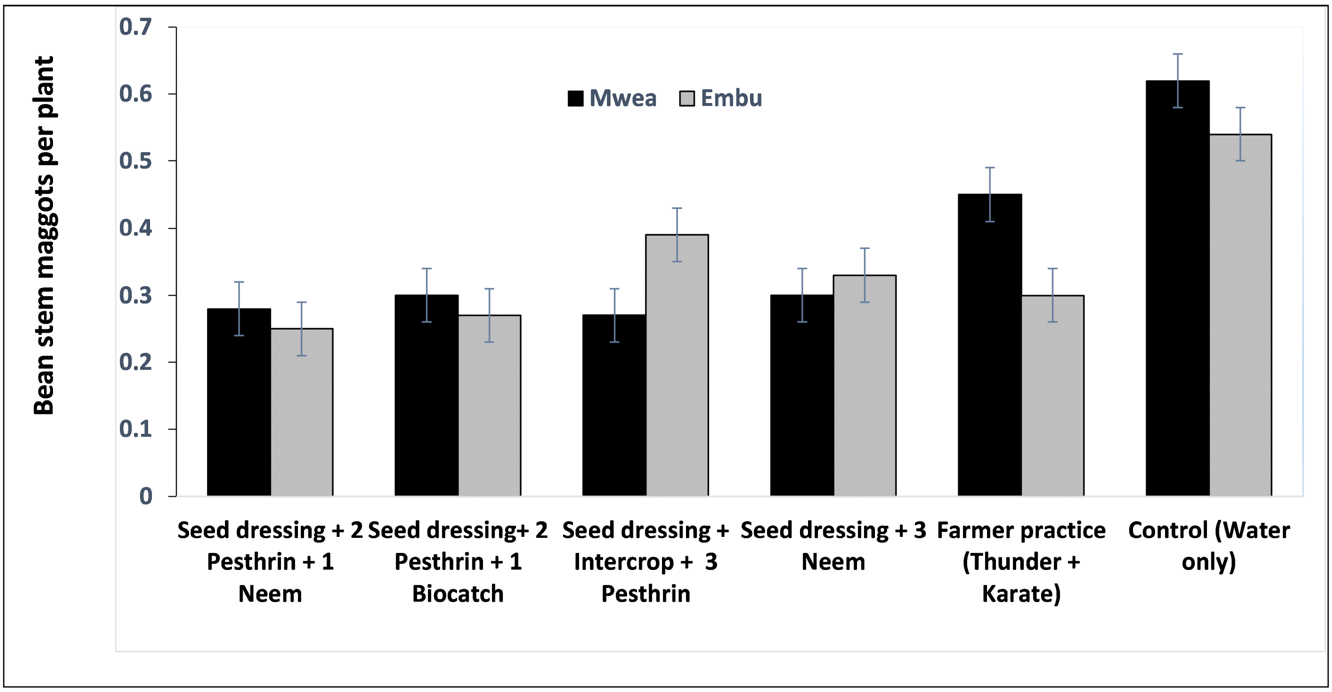

Figure 2. *Number of bean stem maggots per plant on snap bean crop subjected to different pest management options at two sites, Mwea and Embu.*

Pest management options consisting of seed dressing at planting combined with either two pyrethrin sprays followed by a Neem spray or intercropping with maize plus three Pesthrin sprays were the most profitable cost-benefit ratios of 0.7 and 0.8 respectively (Figure 3). The farmer practice consisting of application of Thunder (Imidacloprid 100g/L + Betacyfluthrin 45g/L) and Karate (Lambda Cyhalothrin 25g/Kg) on pest detection had a high cost-benefit ratio of 1.6. This was comparable to the cost-benefit ration for seed dressing followed by two applications of Neem followed by one spray with biological product Biocatch. The yield of pods showing pest damage was significantly reduced in snap bean plots where the seeds were dressed with Moncerene followed by application of either Pyrethrin, Neem or biological control product Biocatch with or without maize intercrop (Figure 4). The least yield of the pest damaged pods was obtained from plots where seeds were dressed with Moncerene, intercropped the bean with maize plus application of three Pyrethrin sprays at vegetative, flowering and early pod formation growth stages. This option had up to 87% reduction in the yield of pods showing pest damage.

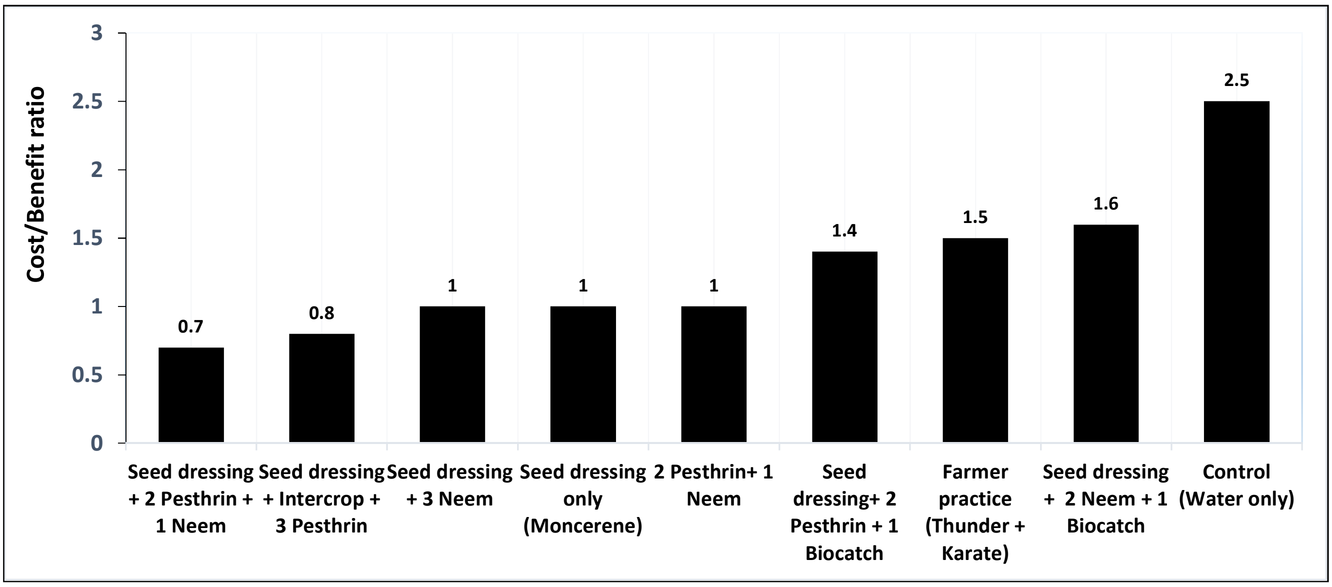

Figure 3. *Cost-benefit ratios for different pest management options in snap bean production.*

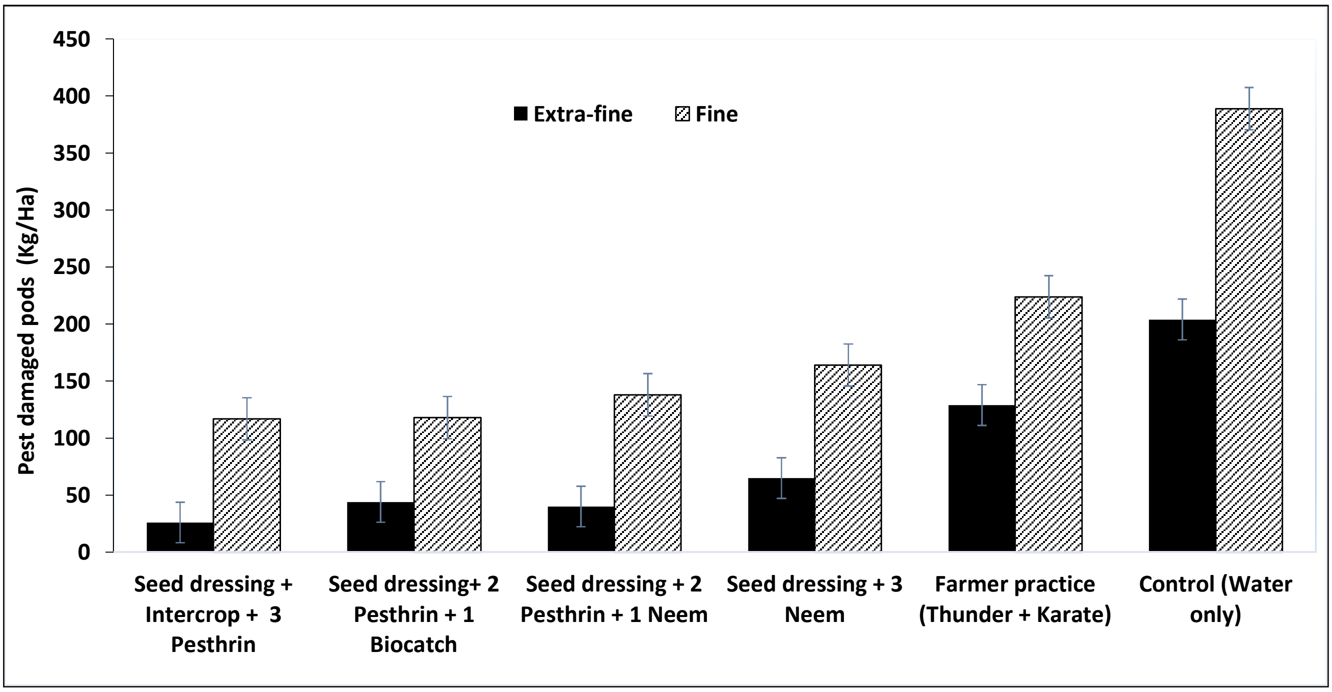

Figure 4. *Yield (Kg/Ha) of pest damaged pods harvested from snap bean crop subjected to different pest management options.*

4. Discussion

Seed dressing combined with pyrethrin and botanical sprays or intercropping with maize significantly (P< 0.05) reduced the whitefly population by up to 57% in snap beans compared to the control. These findings concur with findings by Rao et al. [20] who reported management of pests through intercropping. The results in this study are consistent with results by Hossain et al. [18] on effect of seed dressing and foliar sprays in control of sucking pests in cotton. Zhang et al. [29] also reported control of whitefly in cotton by seed treatment with Imidacloprid. Mandi et al. [13] reported on management of pests through integration of botanical and microbial insecticides.

Similar results have been observed in other studies where seed dressing has been employed successfully for instance, in the management of sucking pests for example whitefly and thrips in cotton [18], management of rice water weevil in rice [30] and management of red spider mites and bean fly (*Ophiomyia phaseoli*) in beans [31]. Intercropping systems have been shown to result in reduced pest incidences compared to monocropping systems [20]. This results prove results reported in Kenya on the management of lepidopteran stem borers on maize and thrips in bulb onions through intecropping [32] [33].

Thrips population was also significantly (P< 0.05) reduced by up to 60%. The results agree with studies by Nyasani et al. [34] and Nderitu et al. [4] in which thrips population in intercropped snap bean was lower than in plots with snap bean alone. Similar results have been reported by Gachu et al. [33] who used vegetable intercrops to management thrips in onion. In this study, bean stem maggot (*Ophiomyia phaseoli*) population was significantly reduced by up to 57%. The results of this study also confirms reports by Allah [31], Elbert et al. [35], Hossain et al. [36] and Malarker et al. [37], Mazzanti et al. [30], Mishek et al. [38] and Ratnadass et al. [39] who showed that seed dressing with insecticides combined with foliar sprays was effective in managing thrips and other pests. The effect of seed dressing results from systemic and contact action of the insecticides in the seed dressing and foliar the sprays [38] [31].

Seed dressing, pyrethrin and botanical sprays or intercropping with maize plus pyrethrin sprays significantly (P< 0.05) increased pod yield up to 163% while the yield of the pest damaged pods was significantly (P< 0.05) reduced by up to 95%. Similar findings have been reported by Radanass et al. [39], Nyasani et al. [34] and Nderitu et al. [4]. Szwejkowska et al [21] reported increase in yield in pea cultivars after seed dressing. Nderitu et al. [4] also reported higher yield in snap beans intercropped with maize while Delkhoshi et al. [40] and El-Mohamedy et al. [41] reported an increase in yield in maize and peas as a result of seed treatment. However, Zilli et al. [42] reported a reduction in yield of soybean as a result of seed treatment with a fungicides. The increased pod yield can be attributed to reduced pest damage as a result of reduction in pest population. The reduction in chemical sprays may also have reduced to stress on the plants leading to better growth.

The reduction in whitefly and thrip population after seed dressing in this study could be attributed to systemic and residual toxicity of the seed dressing insecticide imidacloprid [10] [29]. Imidacloprid in the seed dressing is usually taken up by the plant through the root and translocated to other parts of the plant [43] [30] [19] while foliar sprays reduce pest population through contact and systemic action [44] [35]. Intercropping also reduced pest populations due to increased biodiversity, build up of natural enemies and the intercrop acts as a physical barrier to the pests [33] [34] [20] [45].

5. Conclusion

The results in this study showed that an IPM system based on seed dressing, botanical sprays and intercrppping is effective in managing snap bean pests and consequent increase in pod yield. This reduces the application of synthetic pesticides that have been shown to leave chemical residues in vegetable produce leading to adverse effects on human health and environment. The most effectiv system was found to be seed dressing before planting followed by two pyrethrin sprays at the vegetative stage and one neem spray at early podding or seed dressing with maize intercrop plus three pyrethrin sprays at the vegetative, early flowering and early podding stages.

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