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Effect of Bio-Rational Approaches on the Larval Population and Pigeonpea Pod Damage by *Exelastis atomosa* (Wlsm.)

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Abstract

Effect of bio-rational approaches such as intercropping and application of bio-pesticide on the larval population, pod damage, grain damage and grain weight loss by plume moth (*Exelastis atomosa* (Wlsm.)) infesting pigeonpea (*Cajanus cajan* (L.) Millsp.) was studied. Pigeonpea intercropped with maize, pearl millet, sorghum, rice and black gram had significant effect on the larval population of plume moth when compared with pigeonpea sole crop infestation. The pigeonpea pod damage, grain damage and grain weight loss due to larval infestation in different pigeonpea intercrops and pigeonpea sole crop differed significantly however few exceptions were also recorded. The average larval population, pod damage, grain damage and grain weight loss in different intercrops varied from 0.25 to 0.39 larva/plant, 1.29 to 1.79%, 0.41 to 0.55% and 0.25 to 0.35%, respectively. The pigeonpea sole crop had recorded relatively higher larval population (0.39 larva/plant), pod damage (2.03%), grain damage (0.85%) and grain weight loss (0.59%) than the intercropped pigeon pea. The two sprays of NSKE 5% (first at flowering and pod formation stage and second after 20 days) were found superior in reducing larval population, pod damage, grain damage and grain weight loss. However, the plots devoid of any biopesticidal treatment had maximum larval population (0.68 larva/plant), pod damage (2.75%), grain damage (0.86%) and grain weight loss (0.60%) by *E. atomosa*.

Keywords: pigeonpea, plume moth, *Exelastis atomosa*, intercrop, biopesticide

1. Introduction

The pigeonpea (*Cajanus cajan* (L.) Millsp.) is a perennial legume from the family Fabaceae (Fuller & Harvey, 2006). Since its domestication in South Asia at least 3,500 years ago, its seeds have become a common food grain in Asia, Africa, and Latin America (Van der Maeson, 1995). This is an ecofriendly crop plant of which every part is used by the farmers, grown in marginal lands and it improves soil fertility, prevents soil erosion and favour biodiversity (Nath, 2012). The yield of pigeonpea crop has constrained with various biotic and abiotic stresses. Among the biotic factors more than 200 species of insects have been found feeding on pigeonpea, although only a few of those cause significant and consistent damage to the crop (Lateef & Reed, 1990). Number of these insect pests are found chewing and sucking on pigeonpea plants from seedling to harvest and no part of plant is immune to attack. The insect pests feeding on flowers, pods and seeds constitute the pod borer complex and are of key concern in the pigeonpea growing countries (Grover & Pental, 2003; Gnanesh et al., 2011). The pigeonpea pod borer complex comprised of *Helicoverpa armigera* (Hübner) (pod borer), *Maruca testulalis* (spotted pod borer), *Lampides boeticus* (Linnaeus (blue butterfly), *Exelastis atomosa* Walsingham (plume moth) and *Melanagromyza obtusa* Malloch (pod fly) incurred 30%-80% yield losses in pigeonpea (Sharma et al., 2010). The pod borer complex led by *H. armigera* as major pest incurred 70%-80% of yield loss, and this loss was well supplemented by pod fly (70%-80%), blue butterfly (4%-10%) and plume moth (5%-10%) in pigeonpea (Sharma et al., 2010). In Varanasi region of Uttar Pradesh, pigeonpea crop is attacked by 23 species of insects belonging to 6 orders and 20 families and major insect pests infesting the crop caused damage to the extent of 55.94% pod damage, 32.47% grain damage and 19.19% grain weight loss (Kumar & Nath, 2002). The early and mid-maturing genotypes (determinate type) of pigeonpea suffered most from lepidopteran borer attack, and mid- and late-maturing genotypes (indeterminate type) had more pod fly incidence (Venkateshwarlu & Singh, 1999). Among the various lepidopteran pigeonpea pod borers, four species *i.e. H. armigera*, *E. atomosa*, *L. boeticus* and

Grapholita critica Meyr. have been reported from Varanasi, Uttar Pradesh, India (Singh et al., 2012). Plume moth, (*E. atomosa*) is more common on medium- to long-duration genotypes of pigeonpea causing economic damage and warrants management strategy (Raut et al., 1993, Kumar & Nath, 2003). Conventionally, pest managers have regarded daily pest management circumstances through the eyes of "control" or "eradication" and have largely used pesticides. These pesticides vary in their toxicity and in their potential to cause undesirable ecological impacts. As a result, many growers have implemented Integrated Pest Management (IPM) programs, due to regulatory policy, reduce costs, be more environmentally friendly, or simply because insecticides alone are not working. Ideally, the best approach would be to identify and eliminate only the pest, causing minimal disruption to the system. Until recently, insect pest managers did not have the necessary tools to achieve this goal, but within the last decade, even within the last few years, many new and exciting products have emerged or have greatly improved in efficacy (Childs, 2011). Pest control materials that are relatively non-toxic with few ecological side-effects are sometimes called 'bio-rational' pesticides, although there is no official definition of this term (Grubinger, 1999). The term "biorational" insecticide was coined but not defined by Djerassi et al. (1974). These authors contrasted biorational insecticides to broad-spectrum chemical insecticides by their species-specificity (low toxicity to non-target organisms) and gave examples of naturally derived and synthetic materials. Stansly and Liu (1994) defined the term biorational insecticide as: any type of natural or synthetic material active against pest populations but relatively innocuous to non-target organisms, and therefore non-disruptive to biological control. Target specificity reduces risks to user and consumer health, environmental and ecological stability, and beneficial arthropods, thereby favouring biological control. Stansly et al. (1994) have been able to observe effective biological control of silverleaf whitefly (SLWF) *Bemisia argentifolii* Bellows & Perring in weeds and crop systems in Florida where broad-spectrum insecticides were not sprayed. "Biorational" has only recently been proposed to describe those insecticides that are efficacious against the target pest but are less detrimental to natural enemies (Schuster & Stanley, 2006). The term at times has been used to describe only those products derived from natural sources, *i.e.* plant extracts, insect pathogens, etc. They defined a biorational pesticide as "any type of insecticide active against pest populations, but relatively innocuous to non-target organisms and therefore, non-disruptive to biological control." An insecticide can be "innocuous" by having low or no direct toxicity, or by having systemic or rapid translaminar activity or short field residual, thereby minimizing exposure of natural enemies to the insecticide. The major categories of bio-rational pesticides include botanicals, microbials, minerals, and synthetic materials. However, growers of intensively sprayed, high value commercial crops, would probably be unwilling to suspend insecticides altogether because of perceived risk of losses from pests and insect-vectored diseases. In contrast most of the farmers do not apply insecticide for managing the pigeonpea insect pests rather grow it as intercrop or mix crop to compensate the losses. Pigeonpea being an ecofriendly and biodiversity loving plant allows variety of organisms to grow together (Nath, 2011, 2012). Due to its deep root system, pigeonpea offers less competition to associated crops than some other legumes, and it is often used in intercropping systems with cereals such as millet, sorghum, and maize or with short duration legumes such as cowpea. Its initial growth is slow, and thus as an intercrop it is initially less competitive for light, water, and soil nutrients when grown as a companion crop with short-season cash crops. Intercropping is a multiple cropping practice involving growing two or more crops in proximity. The most common goal of intercropping is to produce a greater yield on a given piece of land by making use of resources or ecological processes that would otherwise not be utilized by a single crop (Ouma & Jeruto, 2010). There are several ways in which increasing crop diversity may help improve pest management. For example, such practices may limit outbreaks of crop pests by increasing predator biodiversity (Altieri & Nicholls, 2004). Therefore, replacement of biorational approaches which includes intercropping, *Bacillus thuringiensis* (Kurstaki) (Btk), and Neem products (NSKE and Nimbecidine) for sole cropping and broad-spectrum insecticides could help create a crop environment where ecofriendly chemical (botanical pesticide) and biological control could co-exist. Biorational approaches achieve several currently desired goals of pest managers and the greater public: for this reason, biorational approaches stand head and shoulders above most other crop protection tools. Since the vast majority of biorationals exhibit no human toxicity, they are exempt from tolerance hence this study was undertaken to determine the effects of intercropping and application of biopesticide on the plume moth larval population infesting pigeonpea pods and their effect on the extent of pod and grain damage and grain weight loss caused by this pest.

2. Materials and Methods

2.1 Location and Treatments

The field experiment was conducted at the Agricultural Research Farm of the Banaras Hindu University, Varanasi, Uttar Pradesh, India. The pigeonpea cultivar 'Bahar' was grown under dryland farming system by adopting recommended agronomic practices as sole crop and intercrop in the row ratio of 1:2 along with maize, pearl millet, sorghum and black gram, while row ratio in case of pigeonpea and seeded rice was 1:4. The spacing between pigeonpea row to row and plant to plant was 90 cm × 30 cm and as such in each treatment plot a total of 50 pigeonpea plants in 5 rows and 10 plants in each row were maintained. The size of each treatment plot was 3.0 m × 4.5 m and as such 126 plots to include 6 main treatments (5 intercrops + 1 sole crop) and seven sub treatments (2 neem products + 1 Btk + 1 untreated control) replicated thrice and as such 126 plots were sown. One metre spacing between block to block and plot to plot were maintained. Thinning was done at 25 and 45 days after sowing to maintain the proper plant to plant distance. The ecofriendly biopesticides *i.e.* NSKE (5%), Nimbecidine (1%) and *Bacillus thuringiensis kurstaki* (Btk) (Halt 1.5%) were applied in two different schedules in the pigeonpea grown as intercrop and sole crop. In the first schedule of biopesticidal treatments were applied at flowering and pod formation stage while in the second schedule two sprayings were done first at flowering and pod formation stage and second at 20 days after first spraying.

2.2 Observations

The absolute larval population of plume moth was recorded following sampling methods used by Nath and Singh (2006) from randomly selected 3 plants per row from 3 middle rows and per se 9 plants (30 per cent plants of 3 middle rows) from each treatment plot at fortnightly intervals starting from flowering and pod formation stage. Five hundred pigeonpea pods were collected from 20 randomly selected plants (25 pods from randomly selected 4 plants per row from 5 rows of each treatment plot (40 % plants per plot) at the time of harvesting to record the healthy and damaged pods and seeds. The plume moth larval damage was marked by a very small circular hole on pod between the ridge of two seeds and it fed on the seed by making a small hole on tender pod and destroying some internal parts of the seed. The number of sound and damaged pods and grains were recorded. The weight of healthy and damaged grains was recorded separately to analyze the percent grain weight loss.

2.3 Statistical Analysis

The percentage of pigeonpea pod damage, grain damage and grain weight loss by the larvae of plume moth were analyzed by using the following formulae:

$$\text{Pod damage (\%)} = NPD/TNPE \times 100 \quad (1)$$

Where, NPD is the number of pods damaged by the larvae of plume moth in each sample and TNPE is the total number of pods examined.

$$\text{Grain damage (\%)} = SD/TNSE \times 100 \quad (2)$$

Where, SD is the number of seeds damaged by the larvae of plume moth in each sample and TNSE is the total number of seeds examined.

$$\text{Grain weight loss (\%)} = (CWDG - AWDG)/CWTPG \times 100 \quad (3)$$

Where, CWDG is the calculated weight (g) of damaged grain (equivalent to the number of healthy grain), AWDG is the actual weight (g) of damaged grain by the larvae of plume moth, CWTPG is the calculated weight (g) of total potential grains (number of healthy and damaged grains).

2.4 Data Transformation

The larval population (x) were transformed as $\sqrt{x+0.5}$ before analysis of variance while percentage data of pod damage, grain damage and grain weight loss were analyzed after arc sine transformation.

2.5 Experimental Design and Data Analysis

To test the effects of the cropping system (sole cropping and intercropping) and biopesticidal treatments on the plume moth larval population, pod damage, grain damage and grain weight loss the respective transformed data were analyzed following randomized block design. The critical difference among the treatments was calculated and compared to know the significance of difference at 5% level of probability (P = 0.05).

3. Results and Discussion

The plume moth larval population, pigeonpea pod damage, grain damage and grain weight loss recorded in the pigeonpea intercrops and sole crop differed significantly. The pigeonpea sole crop had maximum larval population (0.42 larva plant^{-1}). The pigeonpea intercropped with cereals and legume when compared with sole crop had significant difference in the larval population during both the years of studies (Table 1). Pigeonpea intercropped with sorghum and maize sheltered minimum population of plume moth *i.e.* 0.25 and 0.29 larva/plant, respectively. This is in conformity with the findings of Nath and Singh (2006) and Dash et al. (1978)

who had reported the highest infestation of *Helicoverpa armigera* and *E. atomosa* in pigeonpea monocrop in comparison with pigeonpea intercrops. The levels of lepidopteron larval parasitization by the hymenopteran parasitoid are reported to vary greatly among different habitats, plants or plant structures on which the host eggs are located. The mechanisms that may underlie the observed variation in parasitism rates include plant spacing, plant structure, plant surface structure and chemistry, plant volatiles and plant colour. In addition, plants can affect parasitoid behaviour and activity by providing carbohydrate food sources such as nectar to the adult wasps, and by affecting the nutritional quality of the host eggs for progeny development (Romeis et al., 2005).

Table1. Effect of pigeonpea intercropping on the larval population of plume moth infesting pigeonpea

Treatments (Intercrops)	**Population (plant^{-1})**		
	1st year	**2nd year**	**Average**
Pigeonpea + maize	0.30 (0.85)	0.28 (0.84)	0.29 (0.85)
Pigeonpea + pearl millet	0.38 (0.88)	0.34 (0.88)	0.36 (0.88)
Pigeonpea + sorghum	0.22 (0.82)	0.28 (0.85)	0.25 (0.84)
Pigeonpea + rice	0.37 (0.88)	0.32 (0.87)	0.35 (0.87)
Pigeonpea + black gram	0.37 (0.88)	0.34 (0.88)	0.36 (0.88)
Pigeonpea sole crop	0.43 (0.89)	0.40 (0.91)	0.42 (0.91)
C.D. (P = 0.05)	0.04	0.03	0.03

Note. Figures in parentheses are $\sqrt{x+0.5}$ transformed values.

The application of biopesticides significantly reduced the larval population of plume moth (Table 2). Two application of all the three biopesticides was significantly superior over one application in reducing the larval population. Two applications of NSKE 5% was found to be the most effective (0.16 larva plant^{-1}) followed by two applications of Nimbecidine (1%) and *Bacillus thuringiensis kurstaki* (Btk) (Halt 1.5%) in reducing the population of *E. atomosa* while untreated control plots recorded the maximum population (0.68 larva plant^{-1}). These findings are in line with the report of Nath and Singh (2006) and Singh and Nath (2011) who reported the efficacy of NSKE 5% as the most effective treatment against *Helicoverpa armigera* and *Clavigralla gibbosa* Spinola. Singh et al. (2012) report on the influence of intercropping and ecofriendly biopesticides on the population dynamics of pigeonpea podborer complex is in agreement with the outcome of the present study. The efficacy of NSKE is also demonstrated by Patel et al. (1997) who reported NSKE 3% as the most effective treatment comparable with endosulfan and chlorpyriphos for the control of *E. atomosa*.

Table 2. Effect of biopesticides on the larval population of plume moth infesting pigeonpea

Treatments (Biopesticides)	**Population (plant^{-1})**		
	1st year	**2nd year**	**Average**
NSKE 5% (1-spray)	0.30 (0.85)	0.32 (0.87)	0.31(0.86)
Btk (Halt 1.5%) (1-spray)	0.41(0.90)	0.42 (0.90)	0.42 (0.90)
Nimbecidine 1% (1-spray)	0.36 (0.88)	0.33 (0.88)	0.35 (0.88)
NSKE 5% (2-Sprays)	0.16 (0.79)	0.15 (0.79)	0.16 (0.79)
Btk (Halt 1.5%) (2-sprays)	0.28 (0.84)	0.23 (0.83)	0.26 (0.84)
Nimbecidine 1% (2-sprays)	0.22 (0.81)	0.20 (0.81)	0.20 (0.81)
Control	0.68 (1.00)	0.67 (1.02)	0.68 (1.01)
C.D. (P = 0.05)	0.04	0.03	0.04

Note. Figures in parentheses are $\sqrt{x+0.5}$ transformed values.

The pod damage in intercropped pigeonpea ranged from 1.29 to 1.79% while pigeonpea sole crop had higher pod damage (2.03%) (Figure 1). Similar report is made by Sharma and Pandey (1993) who found in their study that intercropping had no marked effect on the pod infestation by *E. atomosa* in medium maturing pigeonpea. The biopesticides *i.e.* NSKE 5% Nimbecidine 1% and *Btk* 1.5% sprayed once and twice (first at flowering and formation stage and second after 20 days) had significantly reduced the pod damage, grain damage and grain weight loss (s). The two sprays of biopesticides were found most effective as compared with one spray. The minimum pod damage was observed in plots treated with two sprays of NSKE 5% (0.67%) followed by two sprays of Nimbecidine 1% (1.06%) and two sprays of *Btk* 1.5% (1.17%) and these were significantly different from all other treatments. The pigeonpea sole crop plots devoid of biopesticidal treatment had the highest pod damage (2.75%). Nath and Singh (2006) reported similar efficacy of NSKE 5% against pod damage by *Helicoverpa armigera* while Sahoo and Senapati (2001) reported 2.65% pod damage by *E. atomosa* in late duration sole crop of pigeonpea and Raut et al. (1993) noticed 0.68 to 18.31% pod damage by *E. atomosa* in various pigeonpea germplasms.

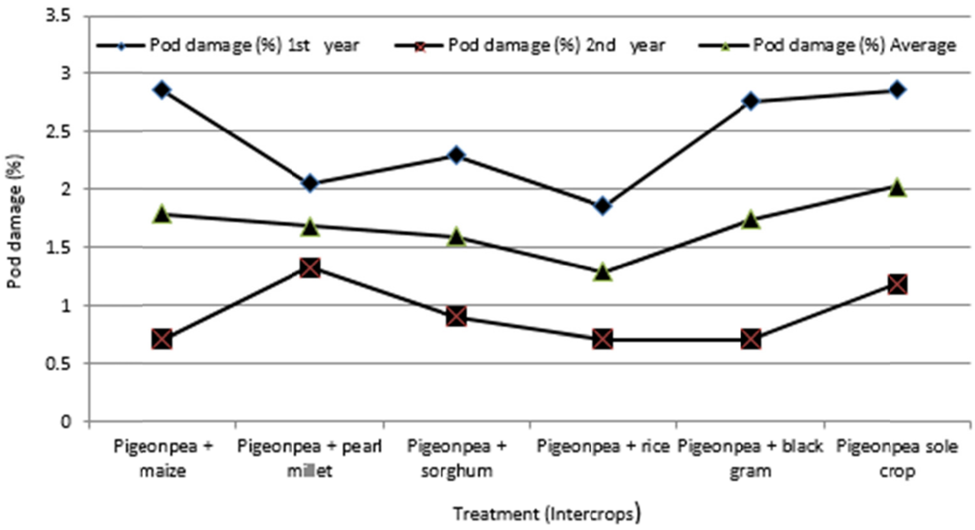

Figure 1. Effect of intercropping on the pod damage (%) by the larvae of plume moth infesting pigeonpea

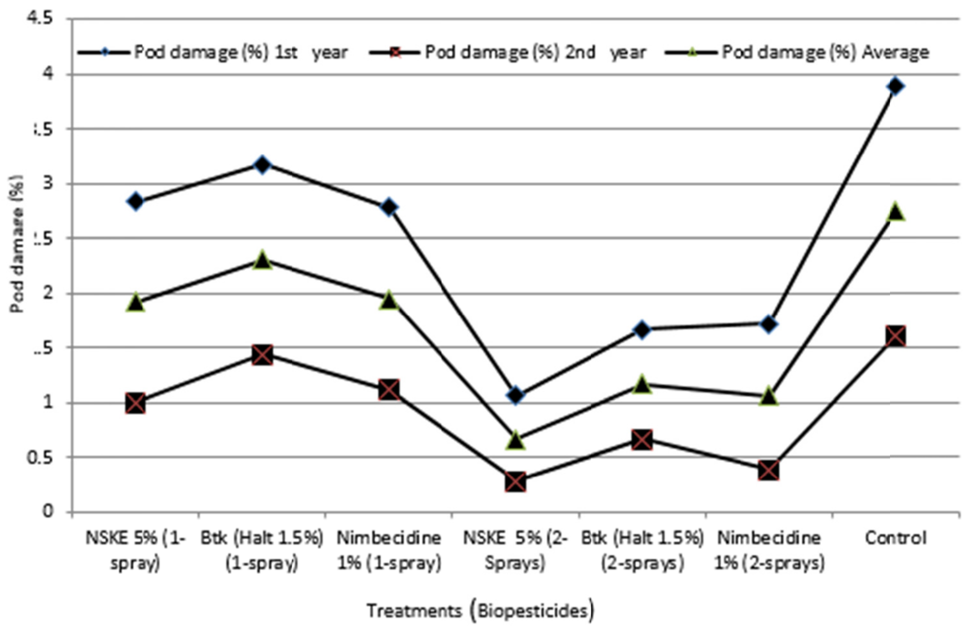

Figure 2. Effect of biopesticides on the pod damage (%) by the larvae of plume moth infesting pigeonpea

The pigeonpea intercropping had significantly reduced pigeonpea grain damage during both the years of study (Figure 3). But two years pooled data showed significant variation among the various intercrops and sole crop.

The maximum mean grain damage was recorded in pigeonpea sole crop (0.85%) while intercrops pigeonpea + rice (0.41%) and pigeonpea + sorghum (0.43%) had the minimum grain damage.

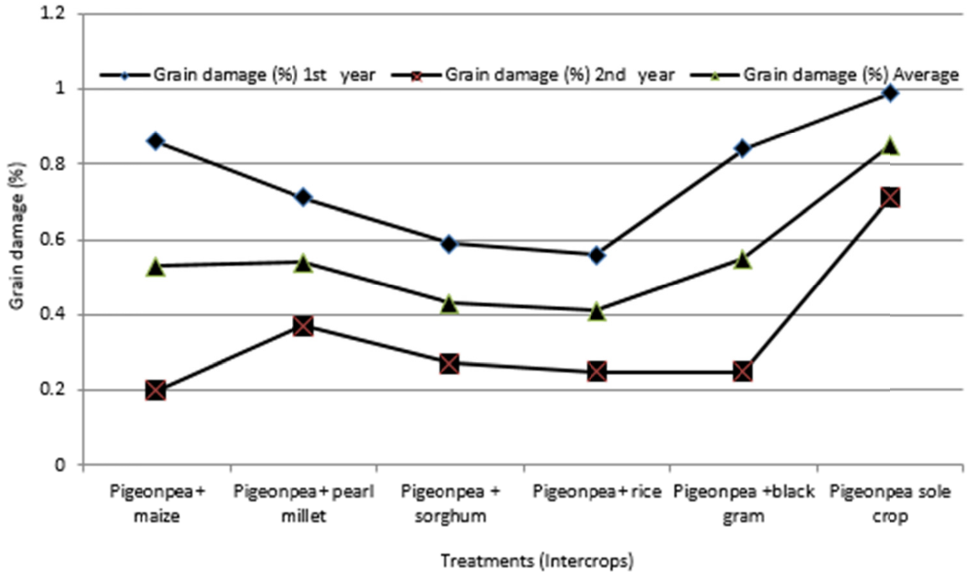

Figure 3. Effect of intercropping on the pod damage (%) by the larvae of plume moth infesting pigeonpea

The maximum efficacy of biopesticides in reducing of grain damage was recorded in plots treated with two sprays of NKSE 5% (0.20%) followed by two sprays of Nimbecidine (0.32%) and *Btk* (0.33%) (Figure 4). Two sprays of biopesticides was found to be most effective and varied significantly from one spray and untreated control plots in reducing grain damage. The pigeonpea sole crop devoid of any biopesticidal treatment showed maximum grain damage (0.86%). Nath and Singh (2008) reported similar effect of NSKE 5% used against a lepidopteron borer *Earias vittella* of okra while Raut et al. (1993) reported 0.44 to 7.57% grain damage by plume moth in various cultivars of pigeonpea.

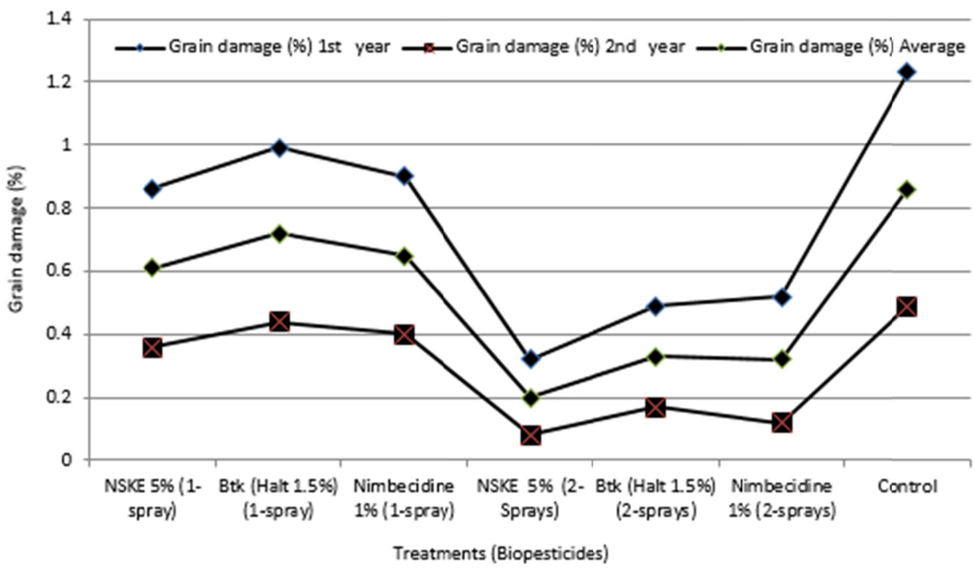

Figure 4. Effect of biopesticides on the grain damage (%) by the larvae of plume moth infesting pigeonpea

Pigeonpea intercropping had significantly reduced the grain weight loss by the larvae of plume moth (Figure 5). The minimum grain weight loss was observed in pigeonpea + rice intercrop (0.25%) while pigeonpea sole crop had maximum grain weight loss (0.59%). The pigeonpea intercrops had recorded lesser grain weight loss as compared to pigeonpea sole crop (Figure 5).

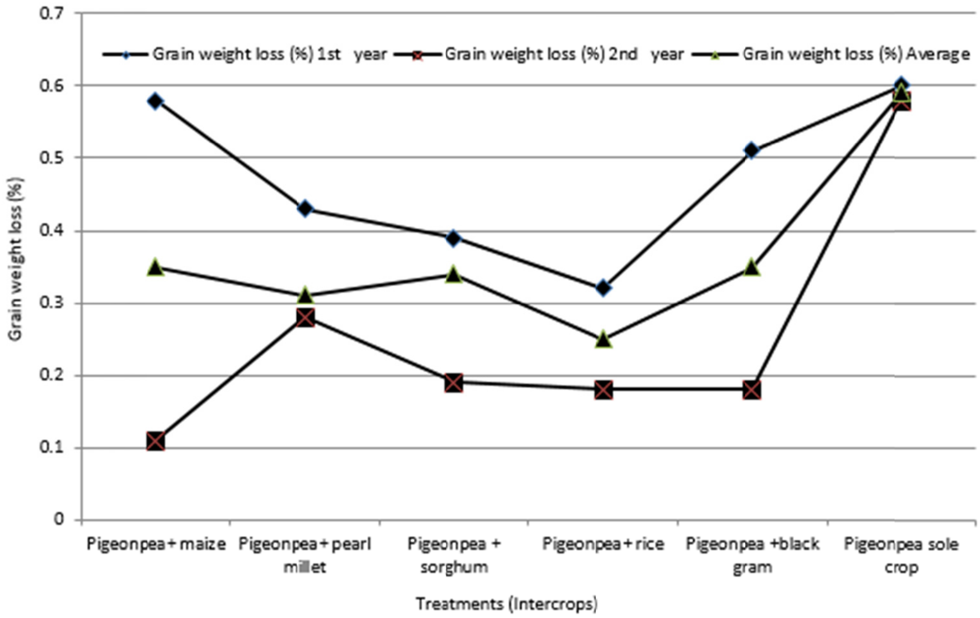

Figure 5. Effect of biopesticides on the grain damage (%) by the larvae of plume moth infesting pigeonpea

Two sprays of NSKE 5% (0.12%), *Btk* 1.5% (0.20%) and Nimbecidine 1% (0.22%) were found effective in reducing the grain weight loss inflicted by larvae of plume moth (Figure 6). The maximum grain weight loss was noticed from the untreated pigeonpea sole crop (0.60%) while Sahoo and Senapati (2001) reported. 0.28% grain weight loss in late duration pigeonpea which is almost half of the grain weight loss observed in the untreated pigeonpea sole crop of the present study.

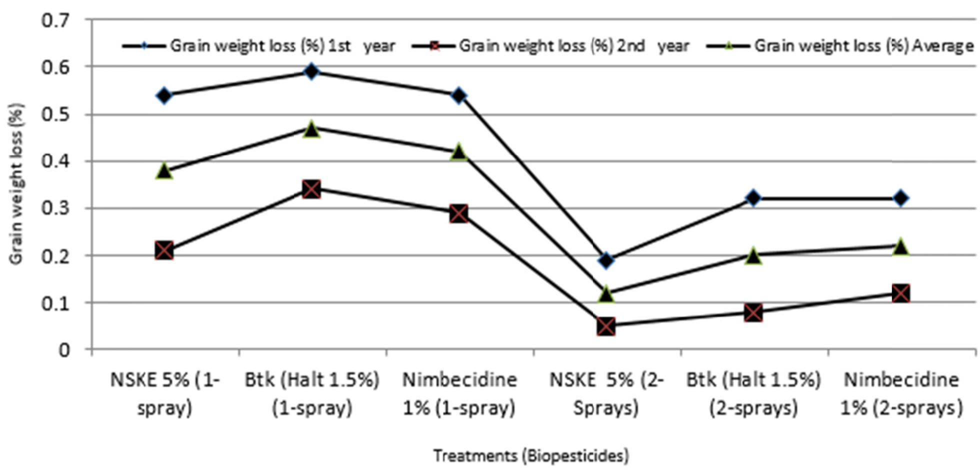

Figure 6. Effect of biopesticides on the grain weight loss (%) by the larvae of plume moth infesting pigeonpea

4. Conclusion

Intercropping of pigeon pea reduced the larval population of plume moth, pigeon pea pod and grain damage and grain weight loss. Sorghum based pigeon pea intercrop is the best combination for managing plume moth infestation followed by maize, rice, pearl millet and black gram based intercrops. Biopesticidal treatments against plume moth infesting pods of pigeon pea showed decline in the larval population, pod damage, grain damage and grain weight loss when compared with the untreated control plots of pigeon pea and the efficacy was in decreasing order of NSKE 5% > Nimbecidine 1% > Btk 1.5%. Two application of biopesticide was found superior over single application of the same pesticide in reducing the larval population, pod damage, grain damage and grain weight loss when compared with the untreated control plots of pigeon pea. The pigeon pea intercropped with sorghum among the intercrops and two sprays of NSKE 5% among the biorational insecticides were the best outcome of the present study for managing plume moth infesting pigeonpea crop.

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