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Effect of weedy culture on population densities, spatial distributions and sampling procedures of *Spodoptera exigua* and *Sesamia cretica* (Lep., Noctuidae) in corn fields

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Abstract

Spodoptera exigua Hübner and *Sesamia cretica* Led. (Lep., Noctuidae) are two important pests of corn. In this study, the effect of weed bands in the corn field, as weedy culture, on population density and damages of the pests were evaluated during two growing seasons (2016/2017). Cumulative insect days (CID) of each lepidopteran pest in weedy culture were compared with non-weedy culture. Results showed that CIDs of *S. exigua* and *S. cretica* in the non-weedy corn culture were significantly higher than the weedy corn culture. There was no significant difference between the total yield in the weedy and non-weedy cultures. Also, determinations of spatial distributions of the pests in the weedy and no-weedy treatments using Taylor's power law (TPL) and Iwao's patchiness (IP) showed that TPL provides a better fit for the data than IP and spatial distributions of both pests on both cultures were aggregative. Moreover, minor differences were observed between spatial distribution parameters of the pests in the weedy and non-weedy cultures. Green's model was used for developing a fixed-precision sequential sampling plan of the pests on the weedy and no-weedy treatments. Optimum sample sizes of *S. exigua* ranged from 532 to 5370 and 428 to 5296 plants and *S. cretica* varied from 297 to 2040 and 43 to 186 plants in the non-weedy and weedy cultures based on the desired precision level (0.25–0.1). Estimated stop lines of non-weedy and weedy cultures for *S. exigua* ranged from 0.000057 to 52.59 and 0.00029 to 58.87 and for *S. cretica* ranged from 1.59 to 111.5 and 2.09 to 98.03 larval cumulative numbers, respectively (0.25–0.1). The performance of the sampling plan was validated by resampling analysis using RVSP software. Results of the study can be used in the integrated pest management program of corn fields.

Keywords: living mulch, lepidopteran pest, ecology, IPM

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1. Introduction

Beet army worm, *Spodoptera exiguae* Hübner (Lep., Noctuidae), is one of the important pests of corn in Iran (Mardani-Talaee *et al.*, 2016) which is native to the south Asian region (Wilson, 1932). The pest's larvae feed on the parenchyma tissues of leaves during first instars and consume the entire leaf, leaving the midrib and other large veins of the leaf during fourth and fifth instars (East *et al.*, 1989). *Sesamia cretica* Led. (Lep., Noctuidae) is another important pest of corn in Iran (Cordero *et al.*, 1998; Yaghubi *et al.*, 2015). Larvae feeding causes dead-heart and longitudinal tunnels in young and older plants, respectively. The plants are broken below or above ear level (Ezzeldin *et al.*, 2009).

Information about biological aspects of pests, e.g., seasonal population dynamics and spatial distribution, is critical for developing integrated pest management (IPM) program (Pedigo, 2002; Rajabpour & Yarahmadi, 2012; Yarahmadi & Rajabpour, 2013). Appropriate sampling plan, i.e., easy to implement and suitable for the rapid decision-making process, is needed to establish successful IPM program (Namvar *et al.*, 2012; Shahbi & Rajabpour, 2017; Kafeshani *et al.*, 2018). In comparison with conventional sampling plan, where a fixed number of samples are used for population estimation, sequential sampling plan can result in a 35–50% reduction in sampling effort (Binns, 1994). Also, the sampling procedure is faster and more reliable because the required sample number depends on the size of the population under survey (Fernandez *et al.*, 2011; Kogan & Herzog, 2012).

Weeds in the field cause more bio-diversity in agro-ecosystem. Therefore, they may affect the insect pests and their natural enemies (NEs) (Andow, 1991; Schellhorn & Sork, 1997). Weeds may influence the pest population by providing a source of shelter and alternative prey/host to NEs, used as a physical barrier, alternation of colonization condition, chemical interaction, etc. (Altieri *et al.*, 1977). Weedy

Fig. 1. Aerial image of geographical position of the experimental field.

Table 1. Comparisons between mean ± SE of *Spodoptera exigua* and *Sesamia cretica* cumulative insect days (CIDs) in the weedy and non-weedy fields (by independent *t*-test).

Species	Year	Weedy condition	Non weedy condition	*t*	df	*P*-value
S. exigua	2016	0.38 ± 0.33	0.91 ± 0.30	2.59	8	0.032
	2017	0.31 ± 0.17	0.97 ± 0.26	−4.2	8	0.03
S. cretica	2016	0.24 ± 0.119	0.86 ± 0.24	5.01	8	0.001
	2017	0.42 ± 0.28	1.01 ± 0.33	−2.97	8	0.018

Table 2. Comparisons between mean ± SE (kg plot^{-1}) of total yield in the weedy and non-weedy fields (by independent *t*-test).

Year	Weedy condition	Non-weedy condition	*t*	df	*P*-value
2016	732 ± 58.10	762 ± 69.85	−7.88	8	0.454
2017	800 ± 37.40	762 ± 23.87	1.91	8	0.092

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Table 3. Spatial distribution statistics of *Spodoptera exigua* and *Sesamia cretica* on corn using Taylor's power law regression analysis.

Species	Weed status	N	Intercept ± SE	Regression slope ± SE	R^2	Spatial distribution	$P_{regression}$
S. exigua	Weedy	11	1.74 ± 0.05	1.85 ± 0.02	0.99	Clumped	<0.0001
	Non-weedy	12	1.73 ± 0.05	1.9 ± 0.02	0.99	Clumped	<0.0001
S. cretica	Weedy	6	1.31 ± 0.06	1.5 ± 0.03	0.98	Clumped	<0.0001
	Non-weedy	9	1.27 ± 0.06	1.6 ± 0.03	0.98	Clumped	<0.0001

Table 4. Spatial distribution statistics of *Spodoptera exigua* and *Sesamia cretica* on corn using Iwao's patchiness regression analysis.

Species	Weed status	N	Intercept ± SE	Regression slope ± SE	R^2	Spatial distribution	$P_{regression}$
S. exigua	Weedy	11	3.12 ± 0.2	3.53 ± 0.82	0.13	Clumped	0.43
	Non-weedy	12	3.23 ± 0.4	4.23 ± 0.57	0.11	Clumped	0.52
S. cretica	Weedy	6	2.19 ± 0.37	2.88 ± 0.65	0.08	Clumped	0.69
	Non-weedy	9	2.81 ± 0.06	2.91 ± 0.7	0.14	Clumped	0.4

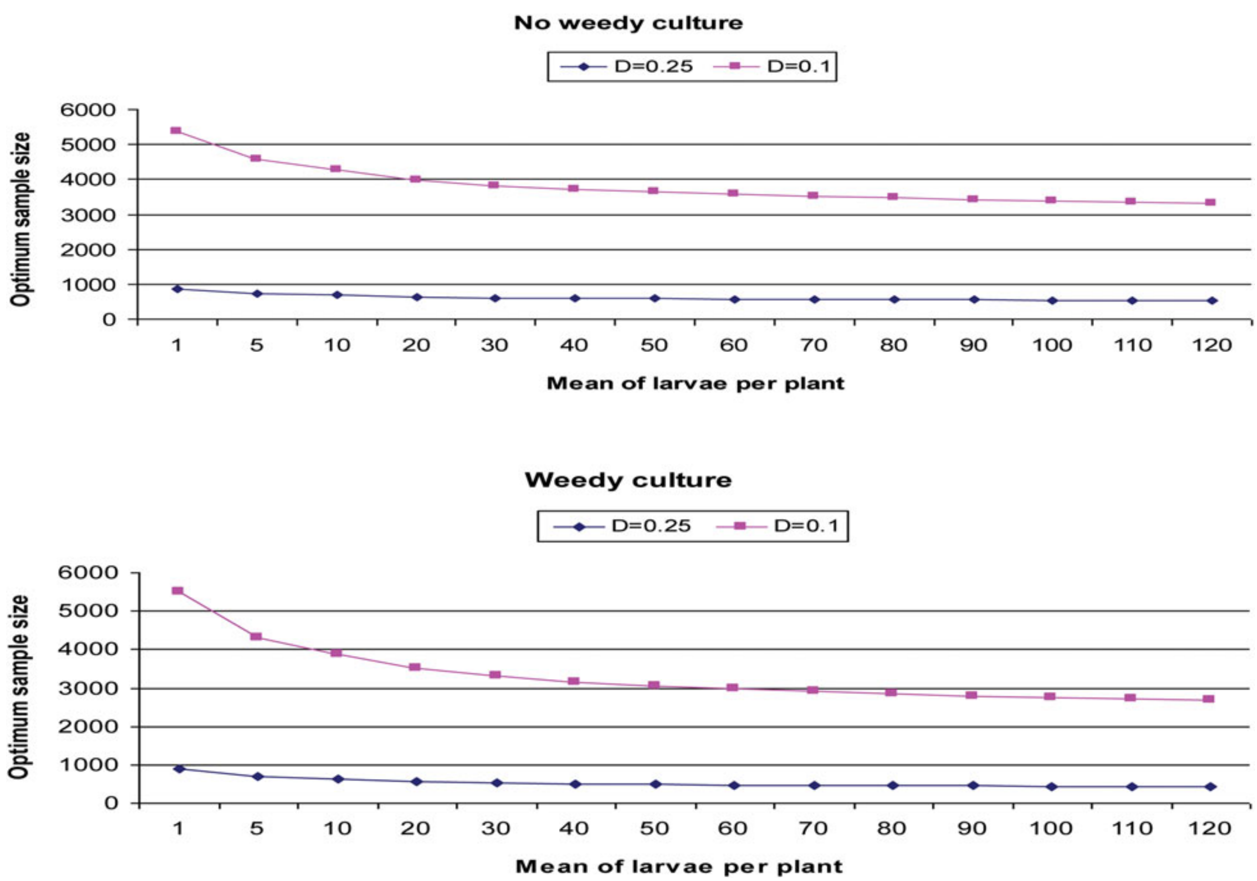

Fig. 2. Optimum sample size of *Spodoptera exigua* on corn in the weedy and non-weedy cultures at the precision levels of 0.25 and 0.1.

culture, allowing selected weeds to grow intermingled with crops, is a special method for vegetational diversification within agricultural fields (Andow, 1991). The effect of weedy culture, which is known by many names including nursery crops, living-mulches, cover cropping, etc., was documented for some pests including *Pseudaletia unipuncta* Haworth (Lep., Noctuidae) on corn (Laub & Luna, 1991), *Bemisia aggentifolii* Bellows & Perring (Hom., Aleyrodidae) and *Aphis gossypii* Glover (Hom., Aphididae) on buckwheat (*Fagopyrum esculentum* Moench) and yellow mustard (*Sinapis alba* L.) (Hooks *et al.*, 1998), *Myzus persicae* Sulzer (Hom., Aphididae) on broccoli (Banks, 2000), *Diabrotica virgifera virgifera* LeConte (Col., Chrysomelidae) on maize (Lundgren & Fergen, 2010), and *S. litura* F. (Lep., Noctuidae) on sesbania (*Sesbanin roxburghii* Merr.), sunn hemp (*Crotalaria juncea* L.), and rapeseed (*Brassicae campestris* L. variety *chinensis*) (Tuan *et al.*, 2014).

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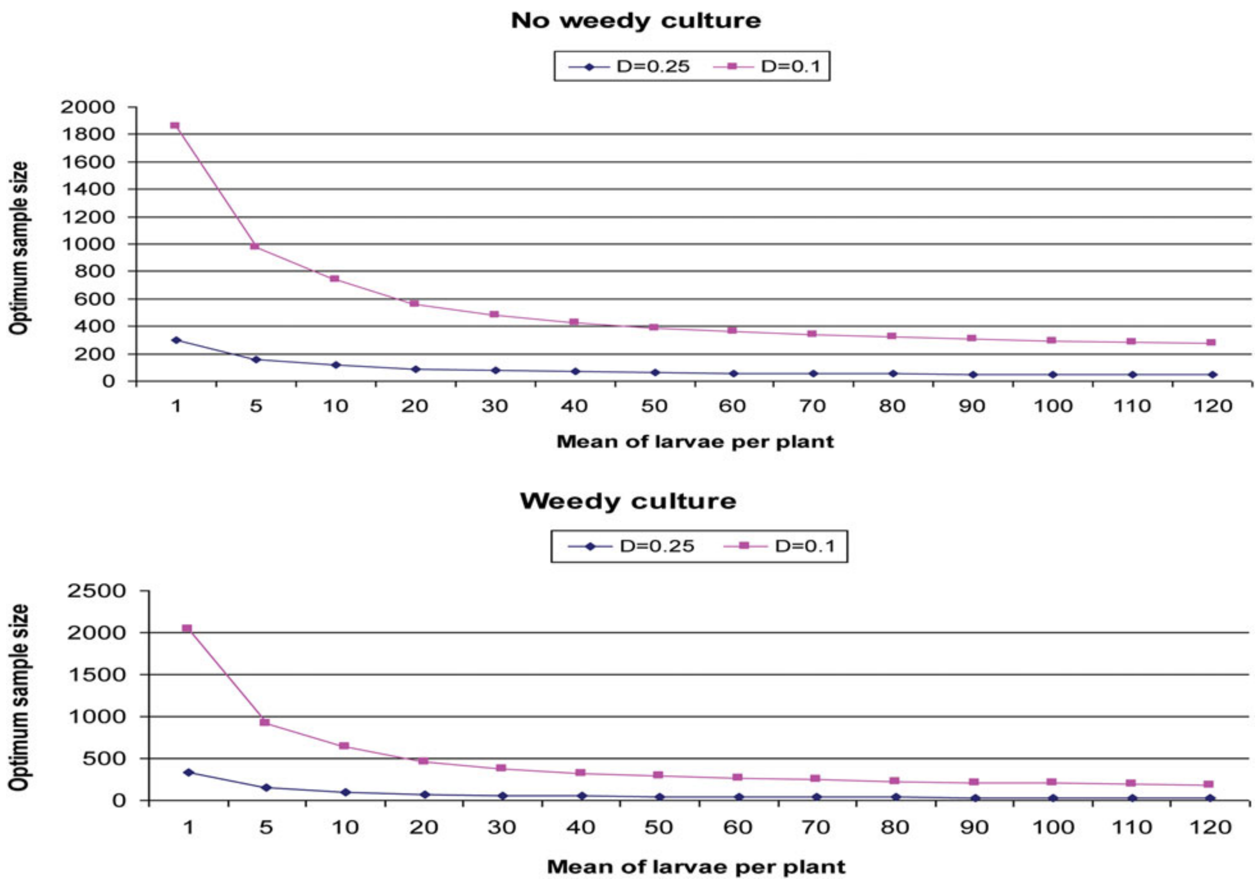

Fig. 3. Optimum sample size of *Sesamia cretica* on corn in the weedy and non-weedy cultures at the precision levels of 0.25 and 0.1.

However, there has been no effort to develop a fixed-precision sequential sampling plan of *S. exigua* and *S. cretica* in the case of the corn field. Also, no previous study was performed on the effect of the weedy culture on the pests' damage and their population densities, spatial distributions, and fixed-precision sequential sampling plans. Therefore, the objective of this study was to estimate and compare damage, population densities, spatial distributions, and fixed-precision sequential sampling plans of the noctuid pests in the weedy and weed-free corn fields.

2. Material and methods

2.1 Description of experimental area

This study was carried out in experimental corn fields, 10,000 m^2, in Shush, Khuzestan province, southwest of Iran (32°14′32.0″N 48°13′46.2″E) (fig. 1). Seeds of a commercial corn cultivar, BC678®, were cultivated (≈75,000–85,000 plants per hectare) in the experimental field. The fields were divided into ten plots (900 m^2) and wide ridges (2 m) were made between them. Cultural practices were carried out according to practical advisements of Khuzestan Agricultural Organization and no pesticides were applied during the study period.

In five plots, randomly chosen, weeds were completely eradicated by applications of Nicosulfuron® 4% SC (0.5 liter h^{-1}) and 2–4-D + MCPA® 67.5 SL (0.5 liter h^{-1}) (Giah Company, Iran). In other plots, a weedy band (1 m wide) was maintained surrounding each plot and weeds of other parts of the field were controlled by the herbicides. By this method, 10% of the total field area had a weedy condition.

2.2 Sampling

Experiments were done during two growing seasons (2016/2017). Samplings were usually carried out at weekly intervals from June to September 2016 and June to October 2017 during the first and second growing seasons, respectively. This period synchronized with phenological steps of the emergence of one shoot to flowering. At each sampling date, ten plants were randomly selected by traveling in an *X*-shaped pattern through each plot. From each selected plant, three leaves from the top, middle, and bottom of the plant were chosen and numbers of live larvae and egg masses on them were separately recorded.

Cumulative insect days (CIDs) of *S. exigua* and *S. cretica* larvae in each plot of the weedy and non-weedy cultures were calculated by equation 1 (Ruppel, 1983):

$$\mathrm{CID} = \sum_{i=1} \left(\frac{x_{i-1} + x_i}{2} \right) \times \Delta t, \qquad (1)$$

where x is the mean number of the larvae on sample day i, x_{i-1}

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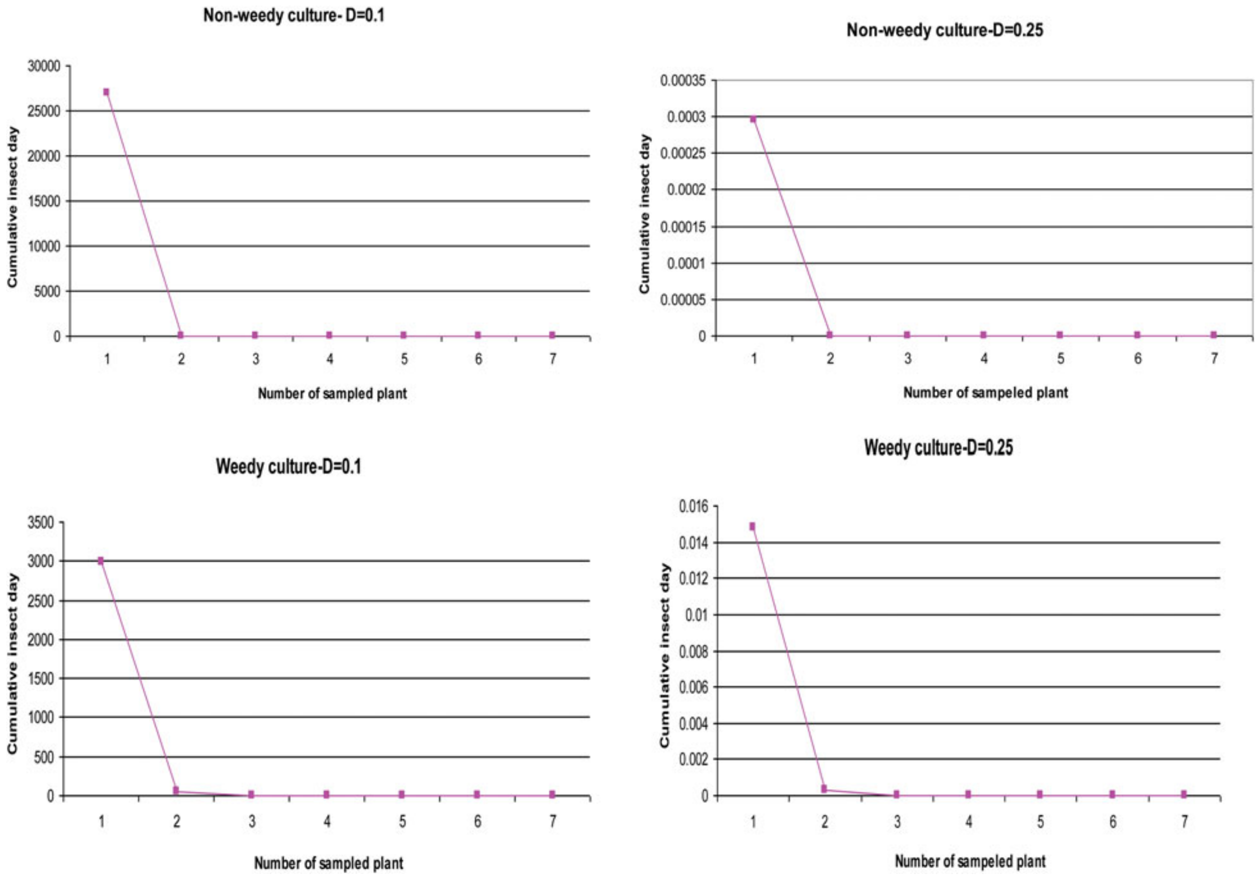

Fig. 4. Fixed precision sequential sampling stop lines for *Spodoptera exigua* on corn in the weedy and non-weedy cultures at the precision levels of 0.25 and 0.1.

is the mean number of the larvae on the previous sample day, and t is the number of days between samples $i-1$ and i.

Harvesting was done during December 2016 and 2017 in the first and second growing seasons, respectively. After harvesting, the total yield of each experimental treatment was separately weighted by an economical mechanical bench scale (Model D500 M, Ohaus Company, China).

2.3 Spatial distribution

Taylor's power law (TPL) and Iwao's patchiness (IP) were used to evaluate the spatial distribution of *S. exigua* and *S. cretica* larvae on corn. TPL describes the regression between $\text{logarithm}_{(10)}$ of population variance and $\text{logarithm}_{(10)}$ of population mean according to equation 2:

$$\text{Log}(s^2) = a + b\text{Log}(\bar{X}), \qquad (2)$$

where S^2 is the larval population variance, $\overline{X}$ is the larval population mean, a is the Y-intercept, and b is the slope of the regression line. The regression slope 'b' is an index of species spatial pattern. When $b < 1$, $b = 1$, and $b > 1$, the spatial distribution pattern of the larvae is uniform, random, and aggregated, respectively (Southwood, 1978; Shahbi & Rajabpour, 2017; Kafeshani *et al.*, 2018). Also, the regression coefficient (r^2) was calculated to obtain goodness of fit of TPL. Two-tailed t-test at $n-2$ degrees of freedom was performed to determine if slope and regression coefficient values of the regression relation are significantly different from 1 and 0, respectively (Snedecor & Cochran, 1980).

IP regression was used to quantify the relationship between mean crowding index (X^*) and mean $\overline{X}$ by using equation 3:

$$X^* = \alpha + \beta\bar{X} \qquad (3)$$

Where,

$$X^* = \bar{X} + \left(\frac{S^2}{\bar{X}}\right) - 1. \qquad (4)$$

Different linear regressions were tested for heterogeneity of slopes (Sokal & Rohlf, 1995) by analysis of covariance of data collected from different growing years using SPSS software (Version 16.0).

Student's t-test can be used to determine if the colonies are randomly dispersed (equations 5 and 6):

$$\textit{In Taylor's power law}: b = 1 t = (b-1)/SE_b \qquad (5)$$

$$\textit{In Iwao's patchiness}: \beta = 1 t = (\beta-1)/SE_\beta, \qquad (6)$$

where SE_b and SE_β are the standard errors of the slope for TPL and IP regression models, respectively. The calculated value of t is compared with the tabulated value of t with $n-2$ degrees of freedom. If the calculated t (t_c) < t-table (t_t), the null hypothesis ($b = 1$) would be accepted and the spatial distribution

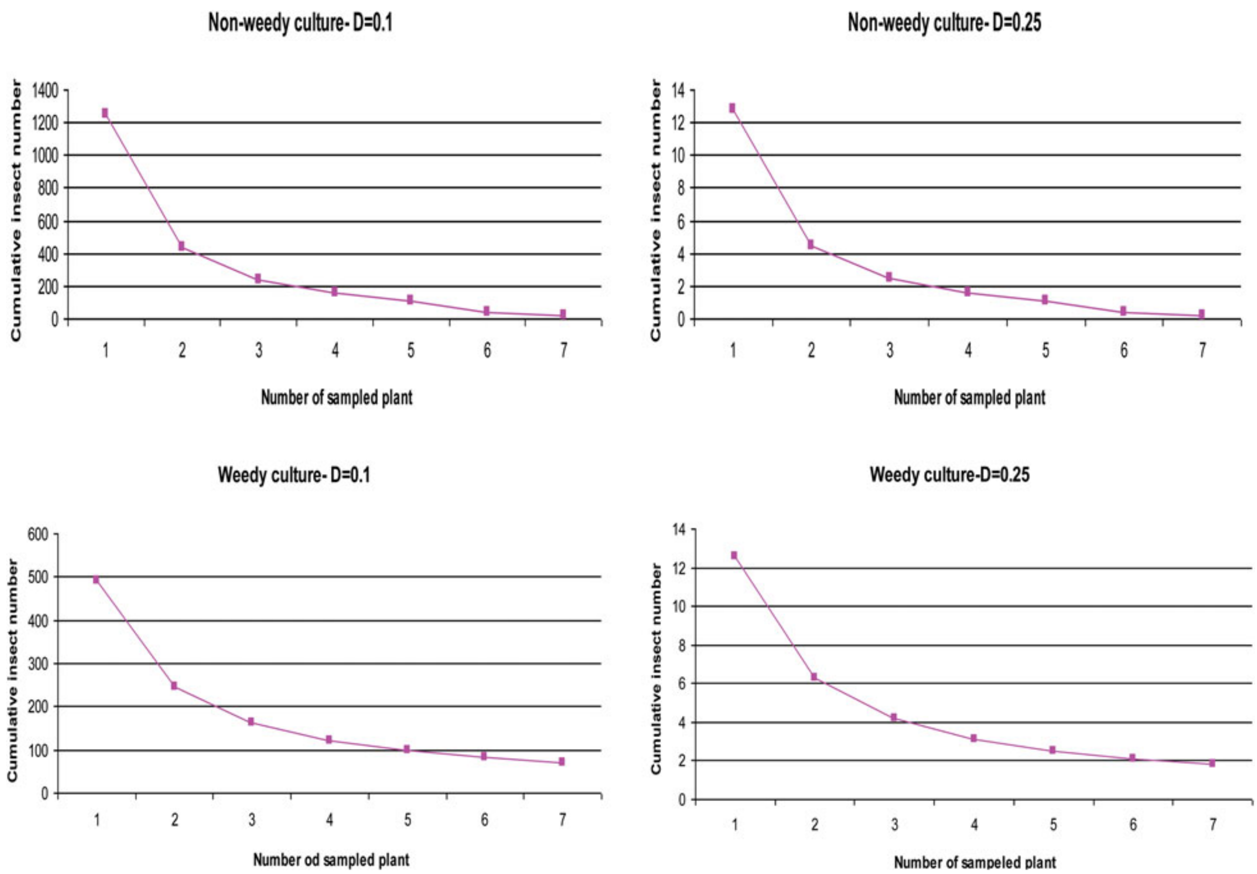

Fig. 5. Fixed precision sequential sampling stop lines for *Sesamia cretica* on corn in the weedy and non-weedy cultures at the precision levels of 0.25 and 0.1.

would be random. If $t_c > t_t$, the null hypothesis would be rejected and if $b > 1$ or $b < 1$, the spatial distribution would be aggregated or uniform, respectively (Sedaratian *et al.*, 2010; Kafeshani *et al.*, 2018).

2.4 Fixed-precision sequential sampling plan

The optimum sample size (n) needed to estimate each noctuid pest species density at two levels of fixed precision, 0.25 and 0.1, was calculated using equation 7:

$$n = \frac{a\bar{X}^{b-2}}{D^2}, \tag{7}$$

where D is a fixed precision level, and a and b are the coefficients obtained from the regression of TPL (Buntin, 1994). Precision levels of 0.25 and 0.1 are generally acceptable for sampling in IPM and research purposes, respectively (Southwood, 1978).

Due to fit data with Taylor's mean-variance model, the Green's method was used and stop lines of fixed-precision sequential sampling were calculated (Naranjo & Hutchison, 1997). The stop lines of *S. exigua* and *S. cretica* in the non-weedy and weedy corn cultures were estimated by equation 8:

$$T_n \geq ((an^{1-b}/D^2)^{(1/(2-b))}), \tag{8}$$

where T_n is the larval cumulative number in n samples, and a and b are the Taylor coefficients, D is the desired precision level.

2.5 Validation of sampling plan

The sequential sampling plan was validated by Resampling for Validation of Sampling Plans (RVSP) software based on Naranjo & Hutchison's (1997) method. The software requires independent data sets to serve as validation data sets (Shhabi & Rajabpour, 2017; Kafeshani *et al.*, 2018). Hence, ten independent data sets with a range of low-, medium-, and high-density levels of each pest larvae were randomly selected from a total of 38 data sets, which were collected from two growing seasons in the non-weedy and weedy corn cultures. The mean densities of these data sets for *S. exigua* and *S. cretica* ranged from 0.002 to 0.12 and 0.001 to 0.082 larvae per plant on the non-weedy corn culture and 0.001 to 0.115 and 0.002 to 0.77 larvae per plant on the weedy corn culture, respectively. The sample size of each data set consisted of 50 plants. Simulations were carried out using 500 resamplings without replacement.

2.6 Data analyses

Experiments were performed in a completely randomized plot design with five replications. Data of CID and total yield

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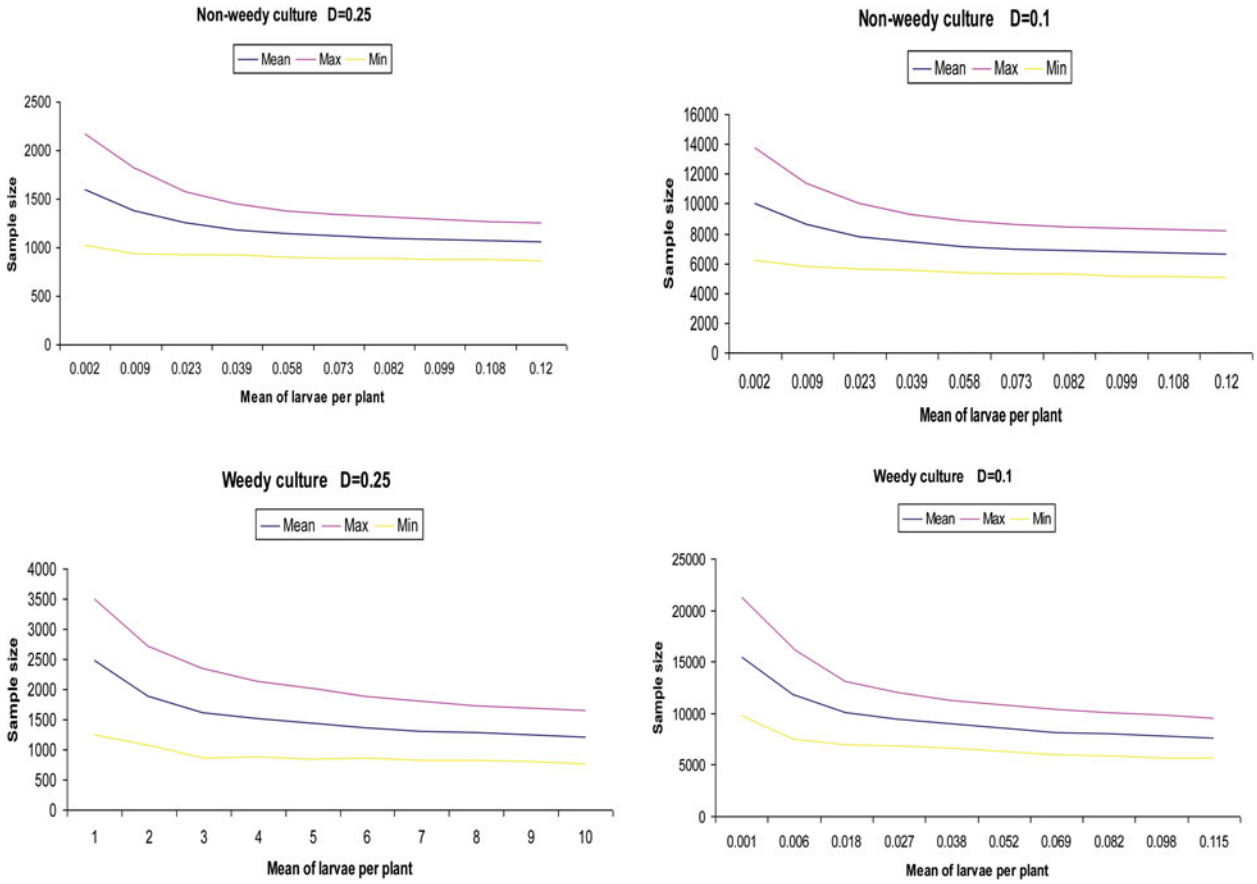

Fig. 6. Summary of re-sampling validation analysis using ten independent data sets of *Spodoptera exigua* on the non-weedy and weedy corn cultures showing the calculated sample size means (±SE) for Green's sequential sampling plan at the precision levels of 0.25 and 0.1.

were compared by analysis of variance using SAS software. When data were not normally distributed, the data were log $(x + 1)$ transformed to meet the assumptions of normality.

3. Results

3.1 Population density and total yield

Population densities of *S. exigua* and *S. cretica* per plant (according to CID) in the weedy and non-weedy cultures are presented in table 1.

Population densities of both noctuid pests in the weedy culture were significantly lower than the non-weedy culture. In the first growing season, CID values of *S. exigua* and *S. cretica* in the non-weedy culture were 2.4- and 3.1-fold the weedy culture, respectively. Similar results were observed during the second growing season.

In both growing seasons, there was no significant difference between total yields of corn in the weedy and non-weedy cultures (table 2).

3.2 Spatial distribution

Spatial distribution patterns and parameters of *S. exigua* and *S. cretica* according to TPL and IP on corn in the weedy and non-weedy cultures are shown in tables 3 and 4, respectively.

TPL provided a significant relationship between variance and mean density for both noctuid pests on the weedy and non-weedy cultures. Although, for both species on the cultures, no significant relationship was observed between mean crowding and mean density in IP regression. For all cases, the aggregation incidence (*b*) of TPL was significantly more than 1 which indicates aggregative dispersions of *S. exigua* and *S. cretica* larvae on corn in both treatments.

3.3 Fixed-precision sequential sampling plan

The optimum sample size of *S. exigua* and *S. cretica* at the fixed precision levels of 0.25 and 0.1 on the weedy and non-weedy corn cultures is presented in figs 2 and 3, respectively. With increasing larval densities, the optimum sample size dramatically decreased. Also, at the precision level of 0.25, the optimum sample size was always lower than the level of 0.1. To estimate *S. exigua* population densities on the non-weedy and weedy corn cultures at the precision level of 0.25 or 0.1, the sample size ranged from 532 to 895 and 428 to 597 plants or 3327 to 5370 and 2679 to 5296 plants, respectively. For *S. cretica*, the optimum sample size for the non-weedy and weedy corn cultures ranged from 43 to 297 and 29 to 326 plants at the precision level

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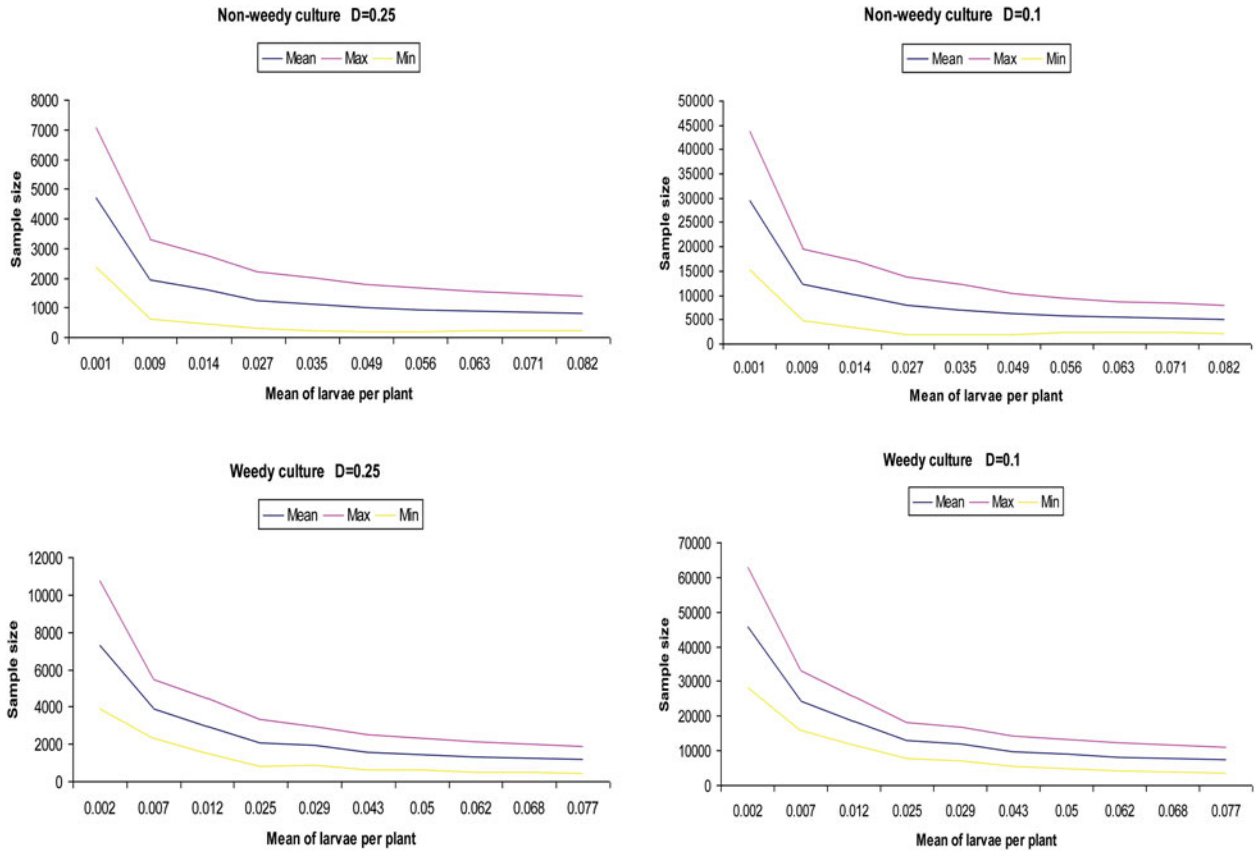

Fig. 7. Summary of re-sampling validation analysis using ten independent data sets of *Sesamia cretica* on the non-weedy and weedy corn cultures showing the calculated sample size means (±SE) for Green's sequential sampling plan at the precision levels of 0.25 and 0.1.

of 0. 25 as well as 274 to 1862 and 186 to 2040 plants at the precision level of 0.1, respectively. Therefore, the study implicated that the optimum sample sizes were different based on the weed condition of the corn field. Moreover, there were differences between the optimum sample sizes of the noctuid pests on corn.

Estimated stop lines using Green's model for *S. exigua* and *S. cretica* on the weedy and non-weedy corn cultures are shown in figs 4 and 5, respectively. Based on the estimated stop lines, numbers of required sampled plants to cross the stop lines are significantly changed. The results indicated that the sampling of *S. exigua* must be continued until the cumulative number of larvae on the non-weedy corn culture reaches 0.000057 larvae per plant at the precision level of 0.25 or 52.59 larvae per plant at the precision level of 0.1. In the weedy corn culture, the sampling should be continued until the cumulative number of larvae reaches 0.00029 and 58.87 larvae per plant at the precision level of 0.25 and 0.1, respectively. For *S. cretica*, the sampling should be continued until the cumulative larval number in the non-weedy culture reaches 1.59 and 111.5 and in the weedy culture reaches 2.09 and 98.03 at the precision levels 0.25 and 0.1, respectively.

3.4 Validation of developed sampling plan

Estimated sample size of *S. exigua* and *S. cretica* on the non-weedy and weedy corn cultures according to resampling analysis using RVSP software is shown in figs 6 and 7, respectively. The mean of sample sizes for *S. exigua* on the non-weedy and weedy corn cultures was 1199 and 1534 plants at the precision level of 0.25 and 7498 and 9593 plants at the precision level of 0.1, respectively. For *S. cretica*, the mean of sample sizes was 1521 and 2493 plants at the precision level of 0.25 as well as 9511 and 15,583 plants at the precision level of 0.1.

For the ten independent data sets covering different densities, the average precision levels for *S. exigua* and *S. cretica* on the non-weedy corn culture were 0.265 and 0.263 at the precision level of 0.25 as well as 0.112 and 0.11 at the precision level of 0.1, respectively (figs 8 and 9). In the weedy corn culture, the average precision levels for *S. exigua* and *S. cretica* were 0.26 and 0.261 at the precision level of 0.25 as well as 0.115 and 0.112 at the precision level of 0.1, respectively (figs 7 and 8). All averages of observed precision levels are close to the desired precision.

4. Discussion

Our data indicated that the weedy culture causes significant reduction in the larval densities of *S. exigua* and *S. cretica* in comparison with the non-weedy culture in the corn field. The reduction may be due to enhancement in NE activities by providing a source of shelter and alternative prey/host. Moreover, the weeds can affect the pest population by applying physical barrier, alternation of pest colonization condition,

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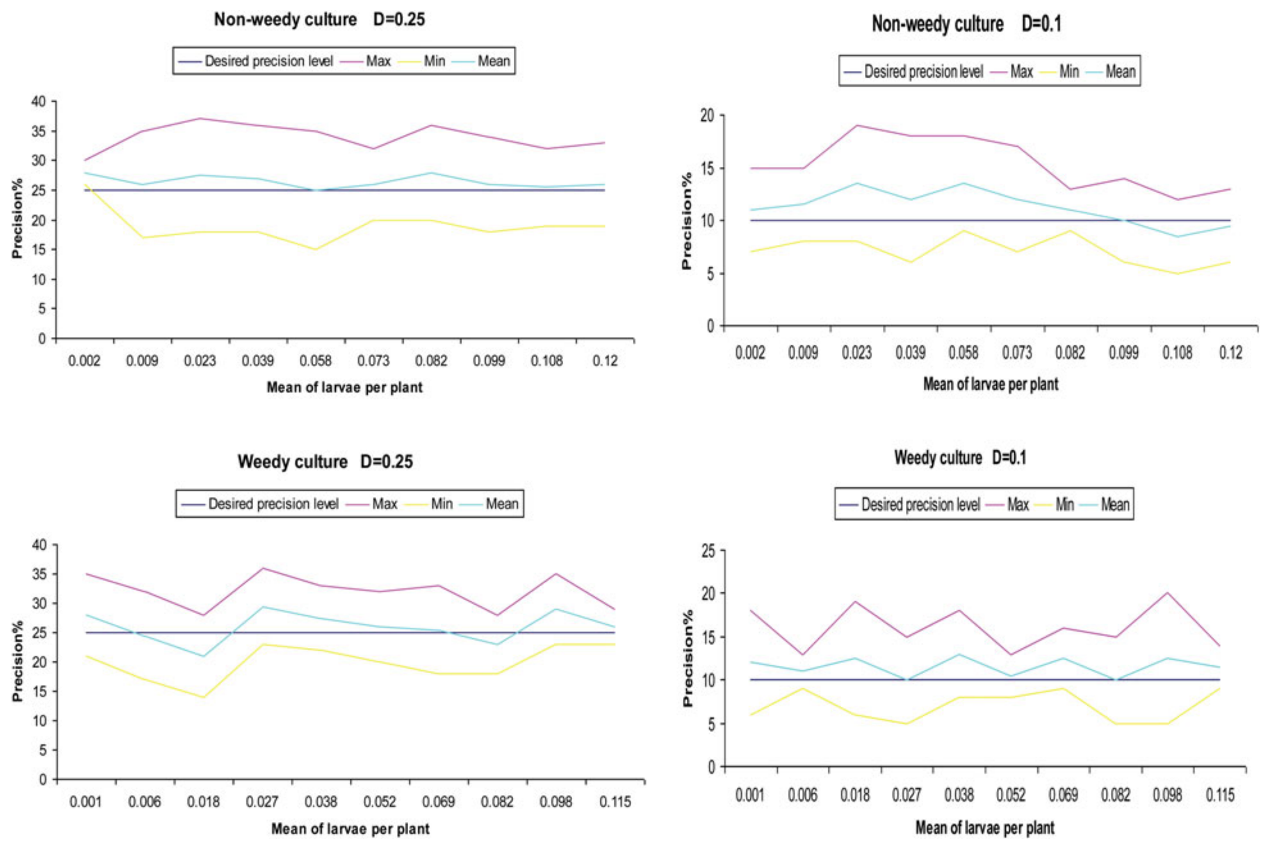

Fig. 8. Summary of re-sampling validation analysis using ten independent data sets of *Spodoptera exigua* on the non-weedy and weedy corn cultures showing the calculated precision level means (±SE) for Green's sequential sampling plan at the precision levels of 0.25 and 0.1.

chemical interaction with the main host plant, and confusing the pest for the main host plant selection (Altieri *et al*., 1977). Abate (1991) demonstrated that the population density of *Heliothis armigera* Hubner (Lep., Noctuidae) larvae and their important NEs, *Tiphia* sp. (Dip., Tachinidae), in the weedy corn culture were significantly lower and higher than weed-free maize culture, respectively. Also, it was reported that when weeds were removed from corn fields, population density of *Agrotis ipsilon* Hufnagel (Lep., Noctuidae) larvae and its damage were enhanced compared to the weedy corn culture. Delaying weed removal until four-leaf stage corn resulted in significant grain yield reductions from both weed competition and *A. ipsilon* damage and only from weed competition (Engelken *et al*., 1990). In a rotation of corn, soybean, and forage crops, it is documented that weed bands, as living mulches, cause a significant increase in ground beetle population (Col, Carabidae) and, therefore, significant reduction in population density of the plant important pest including *Osterinia nubilalis* Hübner (Lep., Crambidae) (Prasifka *et al*., 2006). Totally, the data suggest that population densities of *S. exigua* and *S. creticae* can be reduced on corn when about 10% of total field area had a weedy condition.

Spatial distributions of both noctuid pests were clumped on corn. However, the spatial distribution parameters were different between the pests. Moreover, no significant differences were observed between spatial distribution parameters of the pests in weedy and non-weedy cultures. Spatial distribution of an herbivore insect is influenced by many factors such as insect behavior, environment, the host–plant characteristics, sampling methods, NEs, and so on (Southwood, 1978). The obtained data agree with Mitchell & Fuxa (1987) and Serra & Trumper (2006) who showed that spatial distribution of *Spodoptera frugiperda* Smith (Lep., Noctuidae) is aggregative and TPL fitted the spatial distribution data well. Similarly, it is documented that the spatial distribution of *S. cretica* Led. (Moyal *et al*., 2002) and *Sesamia calamistis* Hampson (Kouame, 1995; Gounou & Schulthess, 2004) on maize is clumped.

Desired precision level and larval density have a critical role to determine the optimum sample sizes of the lepidopteran pests. The relationship between the mean and the variance of the pest densities as expressed by the slope of Taylor's regression leading to the number of samples required to attain the desired precision level is a strong function of density. In this case, a higher sample size is required at the lower pest density (Kapatos *et al*., 1996; Kafeshani *et al*., 2018). The sample sizes of *S. exigua* and *S. cretica* were different according to the pest species. The differences might be attributed to different pest aggregation incidences of each lepidopteran pest. Moreover, the optimum sample size of each pest in the non-weedy corn culture was relatively lower than the weedy corn culture. Minor differences were observed in slope and intercept values of TPL regression between the non-weedy and weedy cultures which may be the main reasons for the difference. If the end user needs a plan with an acceptable trade-off between time invested in sampling and the precision of the

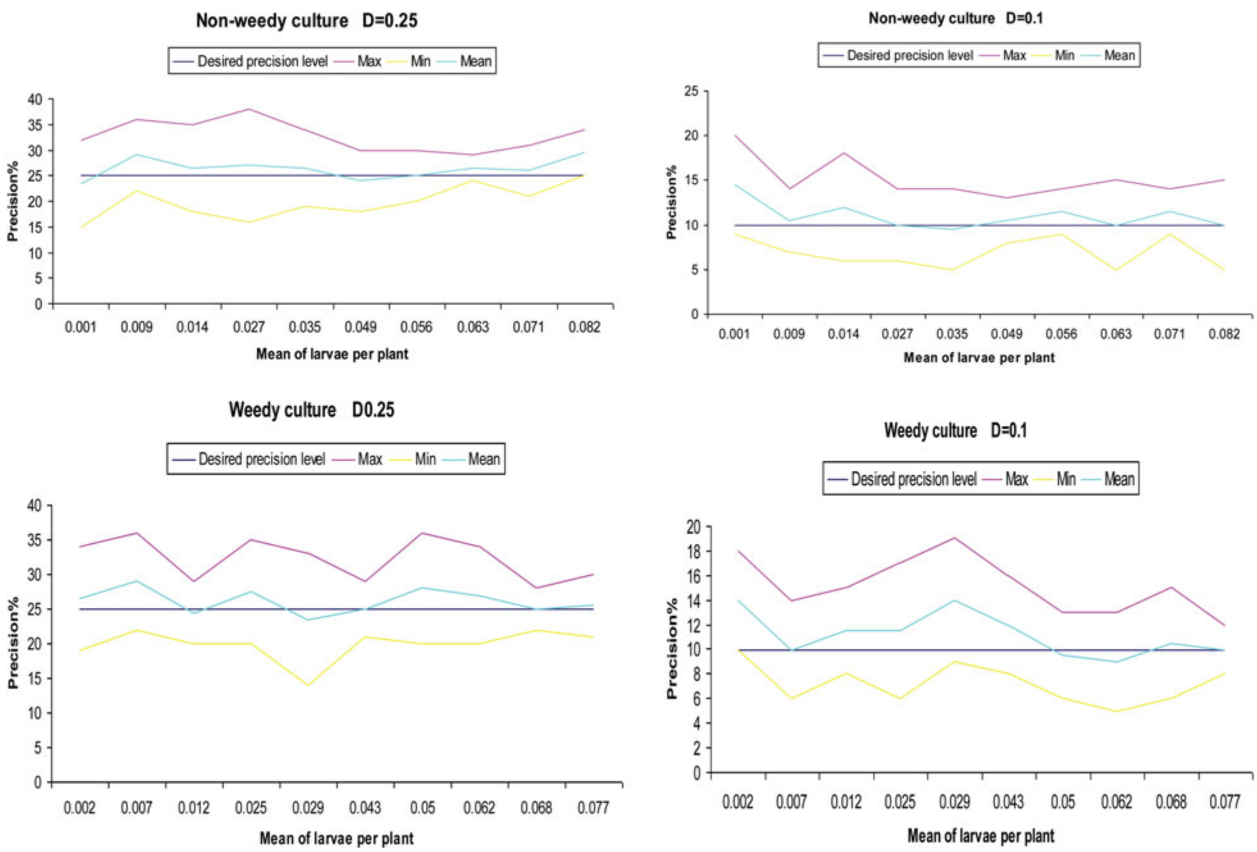

Fig. 9. Summary of re-sampling validation analysis using ten independent data sets of *Sesamia cretica* on the non-weedy and weedy corn cultures showing the calculated precision level means (±SE) for Green's sequential sampling plan at the precision levels of 0.25 and 0.1.

resulting estimation in the whole range of possible densities found in the field, we would recommend using the developed stop-lines of Green's sequential sampling plan for *S. exigua* or *S. cretica* based on the field weedy conditions. No previous study has been performed to develop a fixed-precision sequential sampling plan of *S. exigua* and *S. cerica*. Hence, our result cannot be compared with other studies. Optimum sample sizes of *S. frugiperda* on maize varied 1–12 sample units according to the sample universe (Serra & Trumper, 2006). The sample size was significantly different from our result. The differences may be due to different pest species or sample universe. For *Helicoverpa zea* Boddie (Lep., Noctuidae) on corn, the sample size was 38 and 227 plants at the precision levels 0.25 and 0.1 which is close to our result, respectively (O'Rourke & Hutchison, 2003). Also, our results in line with Moyal *et al*. (2002) showed that the optimum sample size of *S. cretica* on maize is about 200–300 plants at the precision level 0.2.

5. Conclusion

Population densities of *S. exigua* and *S. cretica* in the weedy corn culture were significantly lower than the non-weedy culture. There was no significance between total yield in the weedy and non-weedy corn cultures. Also, the spatial distribution parameters of both lepidopteran pests were not significantly affected by the weed condition of the corn field. Also, optimum sample size and fixed-precision sequential sampling stop lines were different according to the lepidopteran pest species and weed status of the corn field. Results of the study can be used in the IPM program of corn fields.

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