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Short Communication

A New Approach for Evaluation of Egg Laying Behaviour of Alfalfa Weevil, *Hypera postica* (Gyllenhal) (Coleoptera: Curculionidae) during Autumn Using CHAID and MARS Algorithms

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ABSTRACT

The current study was conducted to develop a new approach for revealing egg-laying behaviour of alfalfa weevil, *Hypera postica* (Gyllenhal) (Coleoptera: Curculionidae) laying in alfalfa fields at late fall. Totally, the infected 675 alfalfa plants were evaluated with the objective to predict height of eggs laid by the alfalfa weevil at the plant stem from plant height, number of eggs per cluster, number of egg clusters at the plant stem, and location as potential predictors. In the prediction of height of eggs, CHAID (Chi-square Automatic Interaction Detection) and MARS (Multivariate Adaptive Regression Splines) algorithms were implemented for describing egg laying behaviour of the alfalfa weevil and giving an idea on minimizing loss of the fields, in practice. In conclusion, a new scale developed by CHAID indicated that height of eggs was found higher as the plant height increased from Node 1 (plant height ≤ 23 cm) to Node 10 (plant height > 74 cm), and in MARS, number of egg cluster and plant height affected height of eggs ($P<0.05$), which may help to describe egg laying behaviour of alfalfa weevil, *H. postica*.

Alfalfa weevil, *Hypera postica* (Gyllenhal) (Coleoptera: Curculionidae) is the pest that seriously damages alfalfa not only in Turkey but also in many regions of the world where alfalfa is cultivated (Metcalf and Luckman, 1994; Blodgett and Lenssen, 2004). Larvae seriously damage the alfalfa plant until its first cutting period more than adults. The pest gives a generation annually and lays their eggs at two periods i.e. fall and spring seasons. Especially, it was recognized that they lay many eggs in October and December months of the fall season (Stark *et al*., 1993; DeGooyer *et al*., 1996; Talwar, 2015). Adult alfalfa weevil become active when daytime temperatures reach 15.5°C or higher with adult females being highly fecund laying upwards of 4000 eggs in a lifetime (Coles and Day, 1977). Females which chew holes in stems of the alfalfa plant insert clusters ranging between 5-20 eggs (Litsinger and Apple, 1973). It was reported that fall management applications i.e. late fall harvesting and grazing enabled alfalfa producers to decrease oviposition during fall and winter seasons for avoiding losses of larval damages in spring season (Dowdy, 1984).

In the light of such information about the lifecycle of the pest, it is imperative to decrease the damage of larvae population by grazing and cutting in fall season, meaning that the damage reduces at the fresh period of the alfalfa plants in early spring. In literature, information about preventing losses resulted from the larvae population is of prime importance. Dowdy *et al*. (1992) investigated the effect of late fall cutting, winter grazing and cool-season weed applications on larval densities of the alfalfa weevil in Oklahoma during the years of 1983-1987. Buntin and Boutun (1996) studied the effect of insecticide and spring grazing applications on alfalfa weevil larval densities. However, more sophisticated approaches about laying egg behaviour of the alfalfa weevil to reduce the economic causes resulted from the pest in alfalfa fields are still needed i.e. machine learning algorithms, CART (Classication and Regression Tree), CHAID, MARS

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and ANNs (Artificial Neural Networks). Gözüaçık *et al.* (2018) used CHAID to determine the larval damages of *Bruchophagus roddi* Gussakovskii in alfalfa seeds, Iğdır province, Turkey. However, there is lack of modeling studies on describing laying egg behaviour of alfalfa pests through data mining algorithms addressed above. To the best of our knowledge, egg laying behaviour on alfalfa stems at different alfalfa locations of Iğdır province of Turkey in fall season in the context of describing suitable cutting and grazing height has not yet been discussed. To fill a gap in alfalfa weevil literature, the present study was undertaken to develop a new approach with the scope of integrated pest management (IPM) for illuminating egg laying behaviour of alfalfa weevil, *H. postica* in alfalfa fields and ascertaining optimal cutting heights without insecticide at late fall harvest and winter periods through CHAID and MARS algorithms.

Materials and methods

The study was conducted on different ten alfalfa fields in Iğdır province located in Eastern Anatolia Region of Turkey during October month of the years 2017-18. Samples of 100 plants were selected randomly from various ten places of the fields. A total of 100 plants were examined in the lab by cutting root crowns of ten plants from each of ten places per field. Plant height per plant was measured and eggs were detected by lengthwise cutting each plant examined in the lab. Clusters of eggs and eggs in clusters found in the plant stem were counted and thus the distance from soil level to height of eggs laid by the alfalfa weevil pest was measured. To disclose egg-laying behaviour of alfalfa weevil, *Hypera postica* laying in alfalfa fields at late fall harvest and winter grazing periods; totally, the infected 675 alfalfa plants were assessed. Height of eggs laid by the alfalfa weevil at the plant stem (EGGHEIGHT, cm) was predicted by plant height (PLANTHEIGHT, cm), number of eggs per cluster (EGGNUMBER), number of egg clusters at the plant stem (EGGCLUSTER), and location as predictors. CHAID and MARS algorithms were used for predicting EGGHEIGHT (Akin *et al*., 2017; Gözüaçık *et al*., 2018; Eyduran *et al*., 2019). CHAID analysis was made using IBM SPSS 23 package program (IBM Corp. Released., 2015). For MARS modeling, the earth package of R software was used (Eyduran *et al*., 2019; R Core Team, 2019).

Results

Unlike the previous studies, a scale for describing laying height (EGGHEIGHT) according to various PLANTHEIGHT values was formed by CHAID tree-based algorithm in the present study. The present study was the first report to develop a scale for predicting possible EGGHEIGHT according to various PLANTHEIGHT values within the context of discovering egg laying behaviour of the alfalfa weevil in the alfalfa plants. High Pearson correlation coefficient of 0.874 between actual and predicted EGGHEIGHT values was estimated for the CHAID algorithm ($P<0.01$). The most influential predictor that affected EGGHEIGHT was PLANTHEIGHT, followed by EGGCLUSTER. Overall average of EGGHEIGHT found at the plant stem was 38.709 cm (Node 0). Node 0 was divided into smaller ten subgroups (Nodes 1-10) according to PLANTHEIGHT. It was found that from Node 1 to Node 10, EGGHEIGHT at the plant stem increased as the PLANTHEIGHT increased (Adj. $P=0.000$). This means that the alfalfa weevil preferred the upper fresh part of the alfalfa plant. Average EGGHEIGHT in the Node 1 was 11.676 cm, implying that larval population in spring would be expected to reduce.

Node 2 represented the infected plant group with 23 < PLANTHEIGHT ≤ 29 cm. The average laying height of the weevil alfalfa found in the infected plant group with 23 < PLANTHEIGHT ≤ 29 cm was found 16.807 cm. In the infected plant group with 29 < PLANTHEIGHT ≤ 41 cm, average laying height of them at the plant stem was 24.978 cm (Node 3). The infected plant group with 41 < PLANTHEIGHT ≤ 46 cm (Node 4), average laying height of them at the plant stem was 33.275 cm. Laying height of those laying in the infected plant group with 46 < PLANTHEIGHT ≤ 51 cm (Node 5) was averagely found 37.602 cm. The average laying height of them at the plant stem was 41.536 cm for the infected plant group with 51 < PLANTHEIGHT ≤ 58 cm (Node 6). Similarly, the averages of laying height of them at the plant stems for Node 7, Node 8, Node 9 and Node 10 were estimated 46.353, 51.782, 56.523 and 67.291 cm, respectively. Node 1 was split into two smaller infected plant groups i.e. Node 11 (the infected plant group with PLANTHEIGHT ≤ 23 cm and clusters 1, 2 and 4) and Node 12 (the infected plant group with PLANTHEIGHT ≤ 23 cm and clusters 3 and 7) according to number of clusters formed by the weevil alfalfa at the respective plant stems (10.812 vs. 17.200 cm). Node 6 was split into two smaller infected plant groups i.e. Node 13 (the infected plant group with 51 < PLANTHEIGHT ≤ 58 cm in only a cluster) and Node 14 (the infected plant group with 51 < plant height ≤ 58 cm and clusters 2, 3 and 4) in number of clusters performed by the weevil alfalfa at the corresponding plant stem (36.778 vs. 44.595 cm). With the CHAID algorithm, a new scale was developed for describing EGGHEIGHT. The new scale useful in practice is presented in Table I.

In the MARS, the Pearson correlation coefficient between real and predicted values in laying height was 0.886 ($P<0.01$). All the coefficients in the prediction equation were significant (P<0.01). The prediction equation for MARS algorithm was found as:

Laying Height= 17.9 + 2.47 * EGGCLUSTER2 + 4.04 * EGGCLUSTER3 - 0.675 * max(0, 29 - PLANTHEIGHT) + 0.873 * max(0, PLANTHEIGHT - 29)

In laying height, only an increment of 2.47 cm would be expected for 2 egg clusters whereas for 3 egg clusters, only an increment of 4.04 cm in laying height would be expected. For the infected plants whose height was shorter than 29 cm, laying height would be expected decreasingly from a bit shorter plant height than 29 to the shortest plant height. However, for the infected plant whose height was above 29 cm, laying height of the weevil alfalfa would be expected increasingly.

Table I. The new scale for describing EGGHEIGHT.

Node	PLANTHEIGHT (cm)	EGGHEIGHT (cm) Expected
1	PLANTHEIGHT ≤ 23	11.676
2	23 < PLANTHEIGHT≤ 29	16.807
3	29 < PLANTHEIGHT≤ 41	24.978
4	41 < PLANTHEIGHT≤ 46	33.275
5	46 < PLANTHEIGHT≤ 51	37.602
6	51 < PLANTHEIGHT≤ 58	41.536
7	58 < PLANTHEIGHT≤ 62	46.353
8	62 < PLANTHEIGHT≤ 68	51.782
9	68 < PLANTHEIGHT≤ 74	56.523
10	PLANTHEIGHT > 74	67.291

Discussion

There is still dearth of information about describing suitable laying height in literature. In this respect, under the studied conditions, the obtained MARS equation could be useful for breeders who desire predicting laying height to reduce larval densities. The main purpose of the present study conducted to verify previous studies was to reduce eggs laid in autumn, meaning that spring larvae population would be reduced. It was reported that, in winter period, the pest laid their eggs in November and December months, and in March and April months of the autumn period (Stark *et al*., 1993; DeGooyer *et al*., 1996; Gözüaçık and İreç, 2019). These earlier statements published elsewhere were in agreement with our results. Cutting and grazing applications could reduce spring damages resulted from larvae population. In the Alfalfa weevil population in Oklahoma and southern California, it is likely to be more temporal variability in oviposition and deposit most of eggs from late November to mid-March (Stark *et al*., 1993; DeGooyer *et al*., 1996). This case may be attributed to earlier alfalfa weevil egg hatch in spring (Stilwell *et al*., 2010), which supported our results. An earlier study reported that the peak of egg laying was observed in late fall and early winter in Tennessee (Bennett and Thomas, 1964). Under Cache Valley conditions, the bulk of the eggs were laid in the spring and early summer during the first crop, but the peak egg laying was possible in the late fall and early winter under Tennessee (Bennett and Thomas, 1964) and North Carolina (Campbell *et al*., 1961) conditions. With these reasons, the developed new scale would be beneficial in practice to prevent eggs laying in autumn. In agreement with our results, Burbutis *et al*. (1967) reported in Delaware that the highest feeding damages prior to the first harvest were observed in plants with a great number of fall laid eggs compared with plants including mostly spring laid eggs. However, when larval populations develop firstly from spring-laid eggs then damages could be reduced in early vegetative stages of alfalfa plants. Larger plants are able to withstand greater larval populations (Hintz *et al*., 1976). Larvae obtained from eggs laying in autumn start to damage fresh plants in spring. Dowdy *et al*. (1992) reported a 67% reduction in alfalfa weevil eggs and the reduction of 25% in spring larval numbers in grazed in comparison with non-grazed plots in Oklahoma.

Conclusion

MARS and CHAID indicated that PLANTHEIGHT should be considered as the most significant source of variation in the laying height (EGGWEIGHT) of the alfalfa weevil to reduce loss of the plants damaged by the alfalfa weevil in practice in alfalfa fields at late fall harvest and winter grazing periods. Also, the results will enable plant breeders to achieve valuable clues on the suitable cutting height for providing minimum loss of the infected plants.

Statement of conflict of interest

The authors have declared no conflict of interest.

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