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Short communication

Effect of seasonal weather on incidence of stem fly *Melanagromyza sojae* (Zehntner) in soybean

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Stem fly *Melanagromyza sojae* Zehntner (Diptera: Agromyzidae) is a major pest of soybean in India. The soybean crop is prone to heavy infestation by stem fly at all the stages of growth and development, right from seedling to maturity. Infestations in early crop growth stages rarely exceed 30% but damage at this stage causes high mortality of damaged plants as they are most sensitive thereby reducing the crop stands (Savajji, 2006). At later growth stages of crop the infestation levels may reach 70-100%, however, soybean can tolerate high populations of stem fly with no apparent yield loss (Singh and Beri, 1973; Fand *et al.,* 2018). Its infestation significantly reduces the plant height, number of branches per plant, number of trifoliate leaves, leaf area per plant and dry matter accumulation, thereby reducing the yield significantly.

Recently, *M. sojae* is emerging as a major pest problem in soybean growing areas of the country (Kumar *et al.,* 2009; Gaur *et al.,* 2015). Variety of chemical insecticides like thiamethoxam, chlorantraniliprole, imidacloprid, triazophos, profenophos, etc are being used desperately for management of the stem fly ravages in soybean (Kumar *et al.,* 2009). However, desired control of stem fly is not achieved because of itshidden biology. The maggots and puparia lives concealed inside theleaf or stem of the host crop andseem to be well-protected from insecticidal applications as well as natural enemies like predators and parasitoids (Fand *et al.,* 2018). Planting time of soybean crop is not uniform throughout all the areas in India. Generally sowing span is extended over a period of month (15 June to 15 July), owing in part to the onset of monsoon rains and availability of labour. This results in mosaic pattern of soybean crop with different ages and growth stages in different areas. This adds temporal variability to the already existing spatial variability in seasonal pattern of stem fly incidence in soybean (Fand *et al.,* 2018). The basic aim of present study was to examine the seasonal trend of *M. Sojae* incidence in relation to various weather factors. We establish a relationship between *M. sojae* infestation and prevailing weather factors through fitting of stepwise multiple linear regression.

The seasonal incidence of *M. sojae* was monitored in soybean (*cv* JS-335) at weekly interval during the *kharif* (rainy) seasons (June - October) of 2013, 2014 and 2015. During every week, about 40-50 plants were sampled randomly throughout the field in experimental farm of ICAR-National Institute of Abiotic Stress Management (ICAR-NIASM), Malegaon, Baramati in the District Pune of Maharashtra. Each sampled plant was observed for the presence of stem fly damage, and the numbers of infested plants were recorded and converted to per cent infestation. The values of the weekly per cent infestation for each crop season were plotted against the crop age to see for the seasonal trend. The identity of *M. sojae* was confirmed by Dr Kumar Ghorpade, Scientist Emeritus and Honorary Research Associate in Systematic Entomology, University of Agricultural Sciences, Dharwad, Karnataka, India.

The weekly data on per cent *M. sojae* infestation were averaged over three seasons of study period to obtain mean values. Daily weather data on maximum (T_{max}) and minimum (T_{min}) temperatures, morning relative humidity (RH_m) and evening relative humidity (RH_e) relative humidity and rainfall (RF) for *kharif* seasons of the three corresponding years were obtained from Automatic Weather Station (AWS) installed in the campus of ICAR-NIASM. The weekly values of maximum (T_{max}) and minimum (T_{min}) temperatures and morning (RH_m) and evening (RH_e) relative humidity were computed by averaging daily values over a week. The total amount of rainfall received in a week was used instead of taking average of it. A multiple linear regression was then fitted using a software package SPSS 15.0 for Windows (evaluation version), to establish a relationship between weekly values of *M. sojae* incidence and abiotic factors. The stepwise regression was then fitted to eliminate non-significant weather parameters. The relative importance of different weather factors in pest incidence was adjudged based on their contribution towards coefficient of determination (R^2) and probability (*p*-value) of 'F' and 't' statistics (p-value < 0.05).

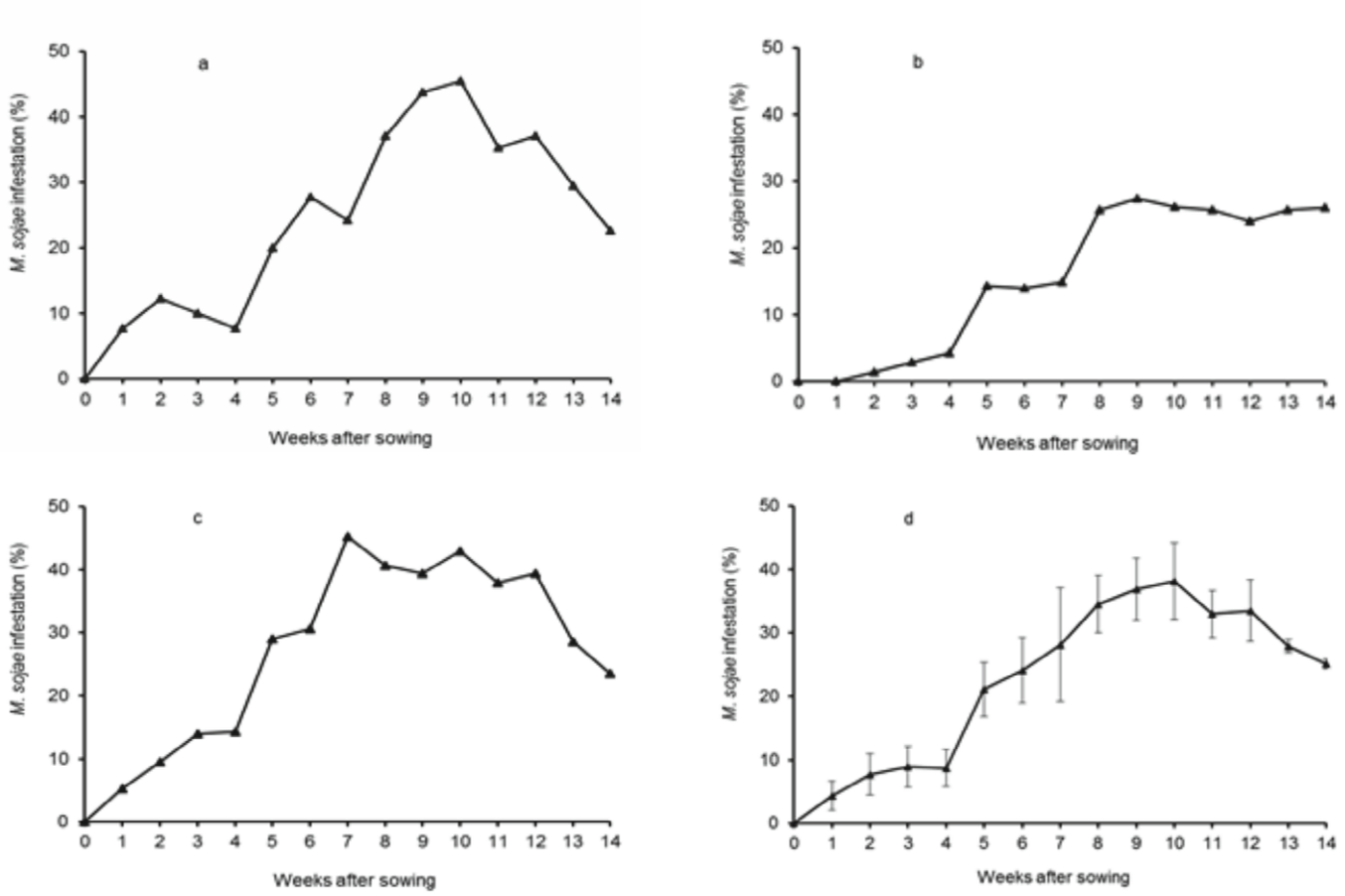

Fig. 1: Seasonal incidence of *M. sojae* on soybean during kharif seasons of 2013 (a), 2014 (b), 2015 (c) and mean seasonal incidence (d)

For validation of model results, the agreement between the observed values and predicted values of *M. sojae* infestation was adjudged through fitting of 1:1 line and estimation of root mean square error (RMSE).

Data on seasonal incidence of *M. Sojae* in soybean when plotted against the crop age revealed that the pest generally infested soybean throughout the crop season (Fig.1). During all the three crop seasons the infestation was initiated at seedling stage, starting from the second week after sowing (30 SMW) and continued up to 14th week (42 SMW) until harvest when livepuparia could still be found inside the infested stems.The infestation was initially low, reached its peak from the seventh till the 10th week (35- 38 SMW) after sowing and declined towards the end of the season. The infestation during the crop season of 2014 was generally low with its peak infestation of 28.0% (Fig. 1b) as against 46.0 % observed during the seasons of 2013 (Fig. 1a) and 2015 (Fig. 1c).

Infestation of *M. sojae* occurred throughout the growing period of soybean during all the three seasons *i.e.* 2013, 2014 and 2015. However, the level of infestation remained low to moderate (<50%). The mean seasonal infestation during soybean seasons of 2013-15 ranged between 4.32 - 38.13 %. Our results are in close agreement with those of Jadhav *et al.* (2013), who reported that *M. sojae* infestation in soybean *cv* JS-335 ranged between 10.87-32.84% at Bailhongal, Dharwad in Karnataka. Generally, high levels of *M. sojae* infestations have been reported by earlier workers. Singh and Singh (1990) reported 72.0–100 % *M. sojae* infestation of soybean *cv* Bragg in Madhya Pradesh. Berg *et al.* (1998) reported 84% infestation of soybean in farmers' fields due to *M. sojae* attack in Indonesia. According to various reports, stem fly incidence in Dharwad district of Karnataka ranged between 15-65% (Anonymous, 2004). Gaur *et al.* (2015) reported *M. sojae* infestation from 30-100% in soybean *cv* Bragg at Pantnagar in Uttarakhand State. These deviances in per cent infestation of *M. sojae* may be due to differences in local climatic conditions, soybean varieties grown and agronomic practices. A variety *Bragg* has been reported as susceptible or low resistant (Gain and Kundu, 1988; Awasthi *et*

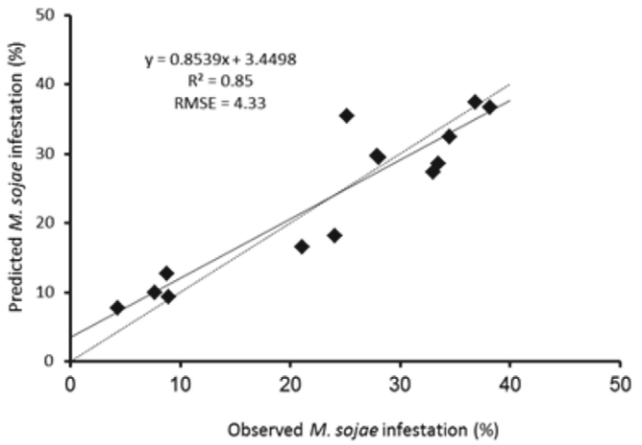

Fig. 2: Relationship between mean observed and predicted values of *M. sojae* infestation

al., 2003), whereas, anotherpopular variety of India JS-335 is reported as moderately resistant to stem fly attack (Awasthi *et al.,* 2003). Further, there is a lot of variation in prevailing temperatures as well as the onset of monsoon and amount of rainfall received during the soybean growing season from North to South regions of the Country.

Regression equation fitted for estimating the relationship between pest incidence and all the five weather variables *viz*., T_{max}, T_{min}, RH_m, RH_e and RF was as

M. sojae infestation (%) = -177.13 +7.23T_{max} -4.923T_{min} +0.66RH_m +0.25RH_e+3.89RF

According to this equation, all the five weather variables could explain 86.8% variability in *M. sojae* incidence (R^2=0.87). However, influence of RH_m and RH_e on pest incidence was not significantly evident as revealed from the higher p-values (RH_m= 0.43; RH_e= 0.71). Therefore, best fit model with only those weather variables contributing significantly towards pest variability was obtained by fitting stepwise regression with elimination of non-significant factors.

The relationship established between *M. sojae* infestation and three weather variables *i*.e. T_{max}, T_{min} and RF is shown below

M. sojae infestation (%) = -25.58 + 5.25T_{max} -5.85T_{min} +4.20RF

The above equation states that only three variables *viz*., $T_{max,}$ T_{min} and RF could account for 85.5% variability in *M. sojae* infestation (R^2 = 0.85). This equation is the best fit for describing the field dynamics of *M. sojae*. There was reasonable agreement between the observed and predicted values of *M. Sojae* infestation (R^2=0.85; RMSE=4.33) (Fig. 2). Thus, the established relationship could sensibly simulate field dynamics of *M. sojae* infestation in soybean.

The weather conditions prevalent during the soybean growing season influenced the level of *M. sojae* infestations in the field. Maximum and minimum temperatures as well as the rainfall during the crop season were found to be most important weather parameters contributing towards population built up of *M. sojae*. Our results are fairly similar to those reported in the literature. Singh and Beri (1973) also reported that stem fly damage was more severe during the rainy season than in the summer season at Pantnagar, Uttarakhand. A significant negative correlation between per cent field infestation of *M. sojae* and minimum temperature has been reported at Pantnagar (Gaur *et al.,* 2015). However, these studies merely correlated *M. sojae* incidence with concurrent weather parameters for a single crop season, and also did not involve identification of key factors affecting population development. In present study, the relationship between *M. sojae* infestation and weather parameters was established using three years field data. Further, stepwise multiple regression procedure was employed to eliminate non-significant factors and to retain only those weather variables contributing significantly towards pest variability. Using similar approach, weather-based forewarning models for insect pests of major crops have been developed and validated using meteorological data (Samui *et al.,* 2004; Sunitha Devi *et al.,* 2019).

Multiple linear regression analysis between field incidence of *M. Sojae* and weather factors revealed that maximum and minimum temperatures and rainfall were found as the key factors affecting population development. Both the morning and evening relative humidity did not affect the field incidence of *M. sojae* in soybean. Reasonably good agreement between observed and estimated values indicated that the established pest-weather relationship could sensibly simulate the fieldincidence of stem fly in soybean.

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