Abstract

Soybean, *Glycine max* (L.) Merr. is one of world's leading oil crop (~20%), providing the cheapest source of high proteins content (~40%) containing all the essential amino acids required by man in adequate quantities less methionine and tryptophan, which make soy products almost equivalent in the quality of the protein to animal sources but with far less saturated fat and zero cholesterol. In developing countries, especially in Africa, soybean is the crop of choice for improving the diets of millions of people. Uganda is the leading producer of soybean in East Africa, and second largest consumer in Africa, after Nigeria. However, its mean yield of 686.44 kg ha^{-1} is still far below the potential of 2800 kg ha^{-1} reported elsewhere. Production is limited by field damage by insect pests and diseases in general, and the Groundnut leaf miner (GLM) (*Aproaerema modicella*) (Deventer) in particular. The GLM presents a major threat to soybean in the country causing grain yield losses from 54 to 100% through larval mining between the epidermis and longitudinal folding of individual leaves leading to decreases in photosynthetic capacity and early defoliation, hampering pod-filling. Most of the commercial varieties grown in Uganda are highly susceptible to GLM. Host plant resistance is preferable to chemical control due to the limited risk on animal health and environment, and its cost effectiveness. Breeding for resistance to GLM in soybean is currently limited by lack of adequate information on heritability and combining ability of the available soybean germplasm and the type of gene action; impeding selection of best parents and effective breeding methods. The breeding process for resistance to GLM in soybean is further complicated by lack of information on biochemical compounds associated with resistance to GLM in Uganda. Moreover, GLM damage is only apparent in second rains in Uganda with no clear explanation as to why. There is a gap in knowledge on the role of rainfall, temperature and humidity and their interactions with soybean genotypes in resistance to GLM. Thus, the objectives of this study were to: (i) Determine the mode of inheritance of resistance to GLM in soybean; (ii) Examine the influence of environment (rainfall, humidity and temperature) on soybean and its interaction with resistance to GLM, and (iii) Identify the different bio-chemical traits involved in soybean resistance to the GLM.

Heritability, combining ability, gene action controlling resistance to GLM, and maternal effect were studied on thirteen parental genotypes comprising five moderately resistant, four moderately susceptible and four susceptible genotypes, which were crossed using a full diallel mating design. The second generation (F_2) plants and the parents were evaluated in an alpha lattice design in two GLM hotspot locations of Iki-iki sub-county in Budaka and Abi Zonal Agricultural Research and Development Institute in Arua district under natural GLM infestation. Results showed that estimates of general combining ability (GCA) effects were significant for GLM incidence and severity scores but not for the number of larvae per plant and grain yield ha^{-1}. The specific combining ability (SCA) effects were non-significant for all the studied traits, suggesting additive gene effects were more important for all of the GLM resistance traits. There was no maternal effect for the inheritance of resistance to GLM. The significant environmental effect observed for all the traits implied an important role in contribution to the total phenotypic variation which suggested that resistant genotypes should be tested in different locations. The moderate and low heritabilities for most traits showed that resistance of soybean to GLM is a quantitatively inherited trait. The parents Maksoy1N, PI615437, PI578457A and NIIGC4.1-2 showed significant negative GCA effects for GLM incidence and severity suggesting that the parents could be selected for breeding of soybean resistance to GLM. Parent PI615437 was also a good combiner for grain yield. Likewise, cross Maksoy1N × PI615437 was superior for grain yield and against GLM incidence.

Crosses Maksoy1N × PI615437, PI615437 × Maksoy1N, and Maksoy2N × Wondersoya exhibited significant negative SCA effect for GLM damage in Iki-iki; and crosses BSPS48C × Wondersoya, NIIGC4.1-2 × PI615437 and PI615437 × NIICG4.1-2 in Arua, indicating that they were the best resistant crosses and could be used to safeguard against GLM in those locations.

To understand the influence of environment conditions on soybean damage by GLM, eighteen soybean genotypes were evaluated in a randomized complete block design experiment replicated three times in the two hotspot locations of study I in 2016 and 2017. The results of this study showed that the GLM incidence and severity mostly depended on minimum and maximum temperature, and relative humidity. GLM incidence and severity increased with a rise in temperature and decreased in relative humidity, providing some insight as to why *A. modicella* severely inflicts soybean during the second seasons (August to December) in Uganda. Furthermore, two genotypes (VI046160 and VI046167) were identified as being resistant, suggesting that they could serve as donor source/parent to breed for soybean resistance to GLM.

To identify the bio-chemical traits involved in soybean resistance to the GLM, different biochemicals were extracted from soybean leaf samples of the 18 soybean genotypes at different growth stages. The result indicated that the total carbohydrate, free tannins, flavonoids, and reducing sugars conferred resistance to the soybean genotypes against GLM damage, and these could be used as biochemical markers to select soybean genotypes with resistance to GLM. The total free tannins contributed more to leaf damage protection compared to the total carbohydrate and reducing sugars. The total flavonoid concentration contributed most to reducing number of GLM larvae per plant. The highest content of the total free tannins, the total carbohydrate, and flavonoids were found in the resistant genotype VI046160.

In conclusion, resistance of soybean to GLM was mostly controlled by additive gene effects suggesting that resistance to GLM in soybean could be improved through early selection. GLM incidence and severity were positively influenced by temperature but negatively by relative humidity and to a lesser extent, rainfall; suggesting that breeders may predict *A. modicella* incidence and severity in Uganda based on environmental factors. Finally, the total free tannins, total carbohydrates, flavonoids and reducing sugars content, which conferred resistance in soybean genotypes to GLM could be used for marker assisted selection.