INITIAL RESPONSE OF SOYBEAN MOSAIC VIRUS, BEAN POD MOTTLE VIRUSES AND *ROTYLENCHULUS RENIFORMIS* ON SOYBEAN

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Abstract

In recent years soybeans (*Glycine max)* have again become an economical alternative as a rotational crop in non-continuous cotton production. Understanding compound stress levels and responses under the presence of reniform nematode (*Rotylenchulus reniformis, RR), soybean mosaic virus* (*Potyvirus,* SMV), and *bean pod mottle virus* (*Comovirus*, BPMV) may give insight into the possibility of compounding disease potential. Microplot test trials were established to study the interactions among nematode and viral pathogens using two conventional soybean varieties; Hartwig as a resistant check (Robbins et al., 2000) and Hutcheson as the moderate to highly susceptible host (Robbins et al., 1996). Virus tissue transferred from pure stocks rendered in the greenhouse was applied during the first tri-foliate stage to each (virus free) test plant. Initial testing has shown RR to reduce shoot dry weight (SDW) by an average of 24.7% in Hartwig and 32.3% in Hutcheson as compared to a healthy control. Other combinations have produced compounding symptoms; however, viral pathogens did not always reduce plant vigor in response to SDW. Yield potential among these varieties showed a significant reduction under combined SMV and BPMV treatments in both Hartwig (32.1%) and Hutcheson (61.7%) as compared to the control. The presence of nematodes in response to yield was not significant under an inoculated pressure gradient of approximately 1100 vermiform life stages per 500cm ^{3}.

Introduction

Soybean acreage across the United States has continued to increase in recent years due to the demand created by the bio-fuels sector, thriving populations and increased market prices. The 2009 soybean crop set records for acres planted (77.5 million) and harvested (76.4 million) as well as setting new records for production. In total 3.36 billion bushels (increase of 13% from 2008) with an average yield per acre of 44 bushels combined to generate over 31.7 billion dollars. Previously this record for average yield was 43.1 bushels set in 2005 (National Agricultural Statistics Service, NASS). Diseases commonly occur when multiple pathogens and their developmental processes act together to effect the epidemiology of a host. This allows for the patterns of health and illness to be associated with populations of parasitic nematodes such as *Rotylenchulus reniformis* (reniform nematode) in conjunction with viral infections. Understanding population dynamics of the reniform nematode in association with virus severity in soybeans (*Glycine max*) can lead to influences of management practices and estimated rotational risk when following crops with similar nematode susceptibility.

High incidences of virus infections have been reported to reduce both yield and grain quality. *Bean Pod Mottle Virus* (BPMV) has become increasingly common throughout the north-central production regions of the United States with estimated losses ranging from 3-52% (Ziems et al, 2007). *Soybean Mosaic Virus* (SMV) is also found in many of the soybean production areas in the US, where primary inoculums are suggested to originate from infected seed (Hill et al., 1980) and estimated to cause losses of 8-35%. Both viruses have the potential to be transmitted by means of infected seed, however, virulent strains which are contained inside the seed can often times go undetected when little to no mottling or mosaic symptoms are present. Infections of SMV and BPMV have the greatest potential for yield reduction when the virus is introduced during early vegetative stages (V2 &V3). Onset of the virus during this stage usually results in abortion of flowers, reduced pod set, reduction in seed vigor (weight) and abundance, and often times visual quality standards as well (Ross, 1969).

Studies on the feeding processes of ectoparasitic nematodes have provided valuable information that can be applied to the behavior of sedentary endoparasitic forms where direct observations on feeding are more difficult. *Rotylenchulus reniformis* has been shown to cause root pruning and necrosis under field conditions and in some crops stunting or dwarfing characteristics were observed. Furthermore, it was found that nematodes showed no distinct pattern to the region of maximum invasion but young roots were infected predominately near the root tip (Birchfield, 1962). The processes of pathogensis can be associated to the manner in which nematodes adversely affect the host either as passive feeders or as endoparasities that induce syncytia or giant cells (Giebel, 1982). Studying the physical effects of multiple avenues of infection and the dynamics of plant health that result will provide insight into predisposition to other stresses and possible additive responses.

The objectives of this study were to analyze both the individual effects of virus to plant interaction and how physical responses are enhanced by multiple virus infections. In addition, understand further the shadowing effects, if any that possible nematode pressure might have in contributing to the aggressiveness of a pathogen. Developing a greater knowledge of the present risks in soybean production would give insight into economical management and prevention strategies.

Materials and Methods

The research was conducted at the Plant Science Research Center (PSRC) greenhouses on the campus of Auburn University. Tests were established during the fall of 2010 under ambient outside temperatures conductive to optimal soybean growth. The trial was designed using two conventional soybean varieties expressing both resistance (Hartwig) and susceptibility (Hutcheson) to the reniform nematode. Treatments consisted of a non treated control, SMV alone, BPMV alone, RR alone, SMV + BPMV, SMV + RR, BPMV +RR, and SMV + BPMV + RR and each treatment was replicated 5 times.

Populations of the reniform nematode were inoculated into 500 cm^3 of sterilized soil at 1135 vermiform life stages. Visibly infected plant tissue grown from greenhouse rendered stock plants was ground in a ceramic grinding pustule containing chilled extraction buffer. Sap was immediately applied to the youngest trifoliate leaves of virus free seedlings using sterile cotton cheese cloth at approximately 10-14 days after planting (DAP). Plants were monitored throughout the duration of the growth cycle and harvested during the R8 growth cycle where 95% of pods have reached mature color. Foliar growth was collected and weighed to obtain SDW and total seed per plot was added to obtain a biomass weight. To obtain population densities each plot containing a treatment of RR or in combination with RR was sampled and enumerated. Lastly a sub-sample of 100 seeds was taken from each plot to assess a seed quality rating in response to individual seed size per treatment. Data was then statistically analyzed using PROC MIXED procedures in SAS ($P \leq 0.05$).

Results

Hartwig and Hutchenson responded differently to the virus/nematode infections. Hartwig was very susceptible to BPMV with estimated reduction of 12 bu/A as compared to a control yield of 34.4 bu/A. Hartwig is considered resistant to nematodes and RR did not reduce the soybean yields alone or when combined with SMV. However, BPMV + SMV + RR did significantly reduce yields but only equivalently to the BPMV treatment which reduced yields 61%. Hutchenson's yields were only reduced by BPMV + SMV. Either virus alone did not reduce the soybean yield. The nematode at this population level did not reduce yields either.

The treatments containing reniform nematode alone proved to induce slight yield increases as compared to the control. Combinations of the viruses SMV or BPMV with the reniform nematode, showed numerically reduced yields throughout both varieties as compared to the RR treatment alone. Although both Hartwig and Hutcheson responded differently to RR reproduction was seen in all treatments. Over all, Hutcheson responded with a reproductive factor (*Rf*) of 3.02 in respect to Hartwig at 1.96.

Within the parameters of this test seed quality (measured in seed size) through a 100 seed sub-sample of every plot showed no statistical differences in either variety. However, further analysis of seed mottling within these treatments will define greater the effects of quality and marketability. Results have shown that with current soybean prices over $13.00 per bushel, up from an average of $9.45 in 2009, the potential loss estimates of 21 bu/A could be devastating at more than $294.00 per acre.

Table 1. Effects of reniform nematode, SMV and BPMV on soybean vigor, shoot dry weight, biomass, seed weight, and predicted yield when grown on Hartwig soybeans in microplots in 2010.

Treatment and rate	Shoot dry weight (gm)	Total seed weight (gm)	100 seed weight (gm)	Reniform	Soybean Yield (bu/A)[z]
1 Control	24.75 a	53.72 ab	17.23 a		34.40 ab
2 SMV	15.25 ab	58.50 a	16.09 a		37.44 a
3 BPMV	24.75 a	35.00 d	15.36 a		22.40 d
4 SMV + BPMV	20.00 ab	36.50 d	15.24 a		23.36 d
5 Reniform	19.25 ab	59.50 a	15.54 a	1969.9 bc	38.08 a
6 SMV + Reniform	22.50 ab	56.50 ab	14.44 a	2954.8 a	36.16 ab
7 BPMV + Reniform	19.25 ab	48.00 bc	15.17 a	2491.3 ab	30.72 bc
8 SMV + BPMV + Reniform	13.50 b	43.50 cd	17.49 a	1525.7 c	27.84 cd
LSD ($P > 0.05$)	9.62	9.62	9.31	705.1	6.15

[z]Yield calculated at seeding rate of 7.4 seeds/ft row to obtain 6 plants/ft row on 30 in spacing.

Table 2. Effects of reniform nematode, SMV and BPMV on soybean vigor, shoot dry weight, biomass, seed weight, and predicted yield when grown on Hutcheson soybeans in microplots in 2010.

Treatment and rate	Shoot dry weight (gm)	Total seed weight (gm)	100 seed weight (gm)	Reniform	Soybean Yield (bu/A)[z]
1 Control	20.50 a	53.50 a	20.72 a		34.24 a
2 SMV	10.75 a	62.50 a	19.36 a		40.00 a
3 BPMV	14.50 a	58.00 a	19.63 a		37.12 a
4 SMV + BPMV	10.50 a	20.50 a	17.86 a		13.12 b
5 Reniform	12.00 a	58.50 a	20.71 a	5001.9 a	37.44 a
6 SMV + Reniform	12.50 a	44.00 a	19.00 a	2877.6 b	28.16 a
7 BPMV + Reniform	17.00 a	49.50 a	18.51 a	2819.7 b	31.68 a
8 SMV + BPMV + Reniform	14.00 a	49.00 a	17.99 a	3032.1 b	31.36 a
LSD (P > 0.05)	21.29	21.29	4.36	3911.5	13.63

[z]Yield calculated at seeding rate of 7.4 seeds/ft row to obtain 6 plants/ft row on 30 in spacing.

Summary and Conclusions

Producing soybeans in soils which contain or have the ability to reach moderate levels of reniform during a growing season have the potential to result in reduced plant vigor and inherently lower yield when SMV and BPMV are active. BPMV proved to be more virulent than expected and reduced plant growth and soybean yield. Reniform at the populations level tested did not significantly enhance or reduce the viral effects on the soybean. However, further examination with higher levels of RR will be necessary to determine if an interaction of viruses and nematode could be further yield limiting.

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