Chalcodermus aeneus (Coleoptera: Curculionidae): Historical Pest Status, Potential for Spread, and Current Management

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Chalcodermus aeneus (Coleoptera: Curculionidae): historical pest status, potential for spread, and current management

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Abstract

The cowpea curculio, *Chalcodermus aeneus* Boheman (Coleoptera: Curculionidae), was first described from samples collected by Chevrolat in Mexico in 1837. Cowpea, *Vigna unguiculata* (L.) Walp. (Fabaceae), has nothing to do with the original hosts of this curculio species, because cowpea is from the Old World, specifically Africa, and *C. aeneus* has never been reported in the Old World. Cowpea curculio has been reported as a major pest of cowpea in the southeastern USA for well over a century. The distribution of *C. aeneus* in the US in 1910 was reported to be in the states of Texas, Louisiana, Alabama, Florida, Georgia, South Carolina, North Carolina, Oklahoma, Maryland, and Missouri. Outside of the US, *C. aeneus* is found in Mexico, Belize, Guatemala, Honduras, Nicaragua, and Peru. This curculio causes tremendous damage to cowpea, so much so that it can render cowpea production unsustainable in a curculio-infested region. Recent deficiencies in viable commercial insecticide controls have led to repeated collapses of acreage in Georgia. In experiments reported here, as much as 60% yield loss occurred with only moderate *C. aeneus* infestations. Heavy curculio pressure shut down cowpea production in our test, even with fairly effective foliar insecticides. Fortunately, *C. aeneus* is not easily transported in cowpea shipments around the world because it reproduces only in green pods, from which it leaves to pupate in the soil before the grain dries. This curculio can be quarantined effectively from large scale movement via shipping due to its reproductive biology, but spreads easily via a land to cowpea crop "bridge." In the southeastern US, research efforts are underway to identify means to reduce the overwintering populations, with the goal of regional eradication sometime in the future.

Key Words: cowpea; southern pea; *Vigna unguiculata*; cowpea curculio; *Chalcodermus aeneus*

Resumen

El curculio (picudo) de caupí, *Chalcodermus aeneus* Boheman (Coleoptera: Curculionidae), se describió por primera vez a partir de muestras recolectadas por Chevrolat en México en 1837. El caupí, *Vigna unguiculata* (L.) Walp. (Fabaceae), no tiene nada que ver con los hospederos originales de esta especie de picudo, porque el caupí es del Viejo Mundo, específicamente África, y *C. aeneus* nunca se ha sido reportado en el Viejo Mundo. El curculio de caupí ha sido reportado como una plaga importante de caupí en el sureste de los Estados Unidos por más de un siglo. Se informó que la distribución de *C. aeneus* en los EE. UU. en 1910 se encontraba en los estados de Texas, Luisiana, Alabama, Florida, Georgia, Carolina del Sur, Carolina del Norte, Oklahoma, Maryland y Missouri. Fuera de los Estados Unidos, *C. aeneus* se encuentra en México, Belice, Guatemala, Honduras, Nicaragua y Perú. Este curculio causa un tremendo daño al caupí, tanto que puede hacer que la producción de caupí sea insostenible en una región infestada por el mismo. Las recientes deficiencias en su control por medio del uso de insecticidas comerciales viables han llevado a colapsos repetidos de acres de caupí en Georgia. En los experimentos informados aquí, se produjo una pérdida de rendimiento de hasta el 60% con solo infestaciones moderadas de *C. aeneus.* La fuerte presión del curculio detuvo la producción de caupí en nuestra prueba, incluso con el uso de insecticidas foliares bastante efectivos. Afortunadamente, *C. aeneus* no se transporta fácilmente en los envíos de caupí en todo el mundo porque se reproduce solo en las vainas verdes, de las cuales sale para pupar en el suelo antes de que se seque el grano. Este curculio puede ser puesto en cuarentena de manera efectiva de un movimiento a gran escala a través del envío debido a su biología reproductiva, pero se propaga fácilmente a través de un "puente" de tierra al campo de caupí. En el sureste de los EE. UU., se están realizando investigaciones para identificar los medios para reducir las poblaciones invernantes, con el objetivo de la erradicación regional en algún momento en el futuro.

Palabras Clave: caupí; guisante del sur; *Vigna unguiculata*; curculio de caupí; *Chalcodermus aeneus*

The cowpea curculio, *Chalcodermus aeneus* Boheman (Coleoptera: Curculionidae), is a serious pest of cowpea, *Vigna unguiculata* (L.) Walp. (Fabaceae), also referred to as southern pea, crowder pea, black-eyed pea, and field pea, and is one of the most culturally significant specialty crops in the southeastern US (the "Southeast"). Cowpea has a rich history throughout the Americas, most likely as an inadvertent importation through the African slave trade. Based on modern genetic analyses, cowpea originated in eastern Africa (Timko & Singh 2008). It is known to be one of the oldest staple crops in Africa (Ng & Marechal 1985), and one of the most drought tolerant (Ewansiha & Singh 2006). In the New World, cowpea was described in Jamaica as early as 1672. In slave ship manifests, "beans" were listed in addition to slaves and livestock, all of which logically had to be sourced from Africa. The first verifiable mainland US report was in 1775 in Florida (Wight 1907). By

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the 19th century, cowpea was the top legume forage crop for cattle in the southeastern US, and had begun to be common in more northern states by 1909 (TenEyck & Call 1909). In the 1920s, greater acreage of cowpea was grown in the US than soybean. Cowpea field production peaked in 1937 at 2.4 million ha (5,836,000 acres), nearly all in the Southeast (Anonymous 1957). At that time, cowpea was planted for grain and hay forage, as well as for human consumption. Around the time of World War II, soybean acreage grew exponentially, while cowpea acreage collapsed, likely because of the ease of soybean mechanization, reduced pest problems, and other factors (Fig. 1). By 2011, the US ranked very low in worldwide production of cowpea, representing a scant 0.1% of world value of this crop, with fewer than 32,400 ha in the US for dry seed production (Quinn & Myers 2002), and less than half of that for fresh or fresh frozen food consumption (C.T. Harvey, personal communication). In the most intensively cropped areas of the Southeast, losses due to the cowpea curculio, *C. aeneus* Boheman, have been so severe in recent decades (Chalfant 1997) that large portions of commercial acreage for fresh frozen consumption have moved out of the Southeast to avoid this single pest (Riley et al. 2015). Economically unacceptable losses are occurring even with the most efficacious labeled insecticides available. There is a near zero tolerance for curculio contaminated peas in the frozen pack process (Chalfant 1997). The inability to consistently control the curculio was one of the reasons for the decline in cowpea production in Georgia from 57,490 ha in 1951 to 1,620 ha in 1997.

Ainslie's 1910 publication, The Cowpea Curculio, placed the distribution of *C. aeneus* in the US in 1910 in eastern Texas, Louisiana, Alabama, Florida, Georgia, South Carolina, North Carolina, and less frequently in Oklahoma, Maryland, and Missouri. Ainslie (1910) stated that "the distribution of this weevil probably coincides with that of the cowpea." This was later confirmed by Arant (1938) who clearly showed distribution in the Southeast. This pest has not been reported as a problem in California (Hall & Frate 1996). More recently, the distribution of *C. aeneus* has been documented for Latin America, México, Belize, Guatemala, Honduras, Nicaragua (Maes & O'Brien 1990), and for *Chalcodermus* sp. (Coleoptera: Curculionidae) in Brazil (Daoust et al. 1985). From our recent studies and based on previous publications, we know that *C. aeneus* is extremely destructive to cowpea (Dupree & Beckham 1955; Chalfant 1996) despite reported "resistance" (Fery & Cuthbert 1975; Chambliss & Rymal 1980). This insect prevents the economical production of cowpea for the fresh frozen market in the absence of better suppression than currently exists.

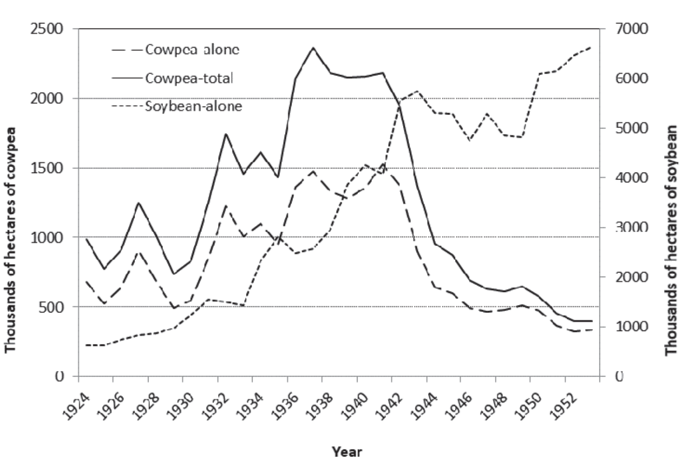

Fig. 1. Acreage of cowpea in the USA planted as a monoculture (alone) and total (included mixed plantings) compared to soybean acreage from 1924 to 1952 based on values from USDA statistics (Anonymous 1957).

In Georgia, southern pea production area has been on the rise in recent years (2,146 ha in 2007; 2,779 ha by 2008; and 3,299 ha in 2009). Increased area accompanied with increasing prices ($18–$20 per bushel) resulted in a state farm-gate value of $12 million in 2009 (Boatright & McKissick 2010). Along with this increase in acreage came more problems with *C. aeneus*. In 2010 and 2011, multiple reports of curculio outbreaks and control failures led to field tests. Field trials indicated that pyrethroid tolerance, or possibly resistance, was on the rise in Georgia (Tables 1 & 2) similar to that reported by N'Guessan & Chalfant (1990). Pyrethroids are the primary insecticides used to control *C. aeneus* throughout the southeastern US, because resistance has already eliminated efficacy of many older insecticides. Consequently, the planted hectares dropped again in 2011 to 2,279 ha, and to 2,010 ha in 2014 (Wolfe & Stubbs 2015).

In the absence of *C. aeneus*, southern pea returns to the farm in terms of land, capital, and management would be approximately $988 to $1,853 per ha (Coolong et al. 2012), with the additional benefit of soil improvement as a nitrogen-fixing green manure crop or a livestock feed crop after peas have been harvested. With pre-harvest costs at $865 per ha, it is an ideal low cost, low risk investment (Ferreira 2011) compared to other vegetable crops. However, in the presence of *C. aeneus*, fresh frozen pea production has been reported to be uneconomical (C.T. Harvey, personal communication). In this report, we documented the severe impact of *C. aeneus* on southern pea production in 2 selected recent field tests, discuss possible management options, and comment on the potential for spread of *C. aeneus* to other cowpea production areas of the world.

Materials and Methods

In Trial 1, cowpea variety 'Pinkeye Purple Hull,' was direct seeded into 2-row plots in 1.8 m × 18.3 m beds on 28 May 2014, and maintained with standard cultural practices at the Lang-Rigdon Farm, Georgia Coastal Plain Experiment Station, Tifton, Georgia, USA. A total of 123 kg per ha of 10–10–10 soil fertilizer was applied to Tift pebbly clay loam field plots at planting. Irrigation was applied at about a half inch per wk with an overhead sprinkler system. In a randomized complete block design with 4 replications, applications of insecticide (Table 1) were made 30 Jun, and 7, 10, 15, and 18 Jul 2014. Cowpea was harvested from 3 m of 2 rows on 24 Jul, and assessed for yield quality. A subsample of 100 pods was separated and categorized as "stung" (curculio oviposition or feeding injury, see Fig. 2) or blemish free. Peas were shelled and percent peas with curculio oviposition wounds were counted. Data were analyzed by PROC GLM and LSD tests for separation of means (SAS Institute 2003).

After 2 yr of continuous cowpea plantings (2014–2015), allowing *C. aeneus* populations to overwinter unimpeded, southern pea variety 'Pinkeye Purple Hull,' was direct seeded in Trial 2 into 2-row plots in 1.8 m × 18.3 m beds on 20 Apr 2016. This was located in the block noted earlier. A total of 168 kg per ha of 5–10–15 was applied to Tift pebbly clay loam field plots at planting. Irrigation was applied at about a half inch per wk with an overhead sprinkler system. In a randomized complete block design with 4 replications, 4 applications of insecticide (see treatments in Table 2) were made on 9, 14, 16, and 20 Jun 2016, beginning at first bloom. Control plots received no insecticide treatment. Peas were harvested from 3 m of 2 rows on 24 Jul and assessed for yield quality. A subsample of 100 pods was separated and categorized as "stung" or blemish free. Peas were shelled and percent cowpea with curculio oviposition wounds were counted. Data were analyzed by GLM and LSD tests for separation of means (SAS Institute, Cary, North Carolina, USA).

Table 1. Efficacy of insecticides on cowpea curculio as indicated by "stung" pods, percent "stung" southern peas, and clean peas produced per subsample and estimated overall per hectare in Trial 1 at the Lang-Rigdon Farm, Tifton, Georgia, USA, in 2014.

Insecticide treatment[1] - formulated product rate per hectare	Wt. (g) of "stung" pods per 100	Percent damaged peas	Total clean wt. (g) peas per 100	Kg of clean peas per ha
Untreated check	488 ab[2]	52% a	130 d	586 b
Besiege® 512 mL + MSO 0.25% v/v	438 abc	25% b	230 c	1296 a
Besiege® 731 mL + MSO 0.25% v/v	525 a	33% b	215 c	1134 a
Double Take™ 2/LEC 292 mL + MSO	525 a	23% bc	249 bc	1267 a
Lannate® 2.4LV 3.5 L + Dibrom® 8EC 1.75 L + PBO-8 292 mL	475 ab	22% bcd	231 c	1114 ab
Brigade® 2EC 468 mL + PBO-8® 292 mL	475 ab	20% bcd	252 bc	1466 a
Karate® 2.08CS 140 mL + PBO-8® 292 mL	475 ab	21% bcd	263 abc	1154 a
Vydate® 2L 4.68 L + PBO-8® 292 mL	413 bc	7% cd	324 a	1392 a
Vydate® 2L 4.68 L	375 c	5% d	309 ab	1432 a

[1]Active ingredients of the commercial products listed are: Besiege = Lambda-cyhalothrin (4.63%) + Chlorantraniliprole (9.26%); Double Take = diflubenzuron (22%) + lambda-cyhalothrin (11%); Lannate = methomyl (29%); Brigade = bifenthrin (25.1%); Karate = Lambda-cyhalothrin (13.1%); Vydate = oxamyl (42%); MSO = Southern Ag methylated seed oil surfactant; PBO-8 = piperonyl butoxide (91.3%).

[2]Means within columns followed by the same letter are not significantly different (LSD, $P < 0.05$).

Results

The results of Trial 1 clearly indicated the severity of *C. aeneus* damage in southern peas, reaching an average of 52% cowpea in the check (Table 1), all of which are not only unmarketable, but also represent a contaminant in the marketable cowpea. All insecticide treatments significantly reduced percent damaged cowpea compared with the untreated check, but Vydate® (oxamyl) was the best treatment. The addition of PBO-8® (piperonyl butoxide) to any insecticide did not significantly enhance control. Vydate® is not currently labeled on southern peas, and will likely not be available unless recent labeling and production issues are resolved. There was no detectable rate response with Besiege®, the lower rate performing as well as the high rate (Table 1). Stink bugs, the other potential pest in cowpea (Nilakhe et al. 1981) that were monitored in our test, never averaged more than 0.08 bugs per 10 plant sample, so all of the yield loss was attributable to cowpea curculio. Brigade® (bifenthrin) provided significant control and the highest amount of clean cowpea per ha (Table 1).

In Trial 2, cowpea curculio damage was so severe that it arrested blossom set (Fig. 2), so that even small subsamples could not be obtained for shelling. In what could be obtained, an average of 43% damaged cowpea was recorded in the untreated check (Table 2). Only Warrior® (lambda-cyhalothrin) and Vydate® insecticide treatments significantly increased clean cowpea in the subsamples of cowpea compared with the check. All of the yield loss was attributable to *C. aeneus* because stink bug populations were low. The only labeled product that provided significant control (lambda-cyhalothrin, Warrior®, Table 2) was insufficient to make the field worth harvesting for a commercial grower, and the percent "stung" or grub infested peas indicated a net increase in the *C. aeneus* population for subsequent plantings based on previous experience with *C. aeneus* population monitoring (Riley et al. 2015).

Discussion

It is very clear from the 2 tests presented that *C. aeneus* is the key pest of cowpea in the Southeastern US. Even with typical pest pressure, as in Test 1, 60% of the potential production of clean cowpea is lost without effective sprays. Even with this limited success, contamination of cowpea (5% in the best treatment in this test) can further degrade fresh frozen cowpea value. If populations are allowed to build to extremely high levels, as in Test 2, this curculio effectively shuts down commercially viable fresh frozen cowpea production. This occurs even with fairly efficacious foliar insecticides. Thus, this pest can be considered a limiting pest of crop production, i.e., where it occurs in high numbers there is no viable cowpea production. Also, the potential for

Table 2. Efficacy of insecticides on cowpea curculio as indicated by "stung" pods, percent "stung" southern peas, and clean peas produced per subsample and estimated overall per hectare in Trial 2 at the Lang-Rigdon Farm, Tifton, Georgia, USA in 2016.

Insecticide treatment[1] - rate per hectare	Wt (g) of "stung" pods per 100	Percent damaged peas	Total clean wt (g) peas per 3 m	Kg of clean peas per ha
Untreated check	77 d	43% a*	9.9 cd*	18 cd
Warrior II® 140 mL	579 a	36% a	107.8 a	193 a
Venerate™ XC 18.7 L	111 bcd	55% a	8.5 cd	15 cd
Grandevo® 3.37 kg	104 cd	42% a	3.4 d	6 d
Avaunt® 0.42 kg	245 b	34% a	17.2 cd	31 cd
Apta™ 1.97 L	625 a	35% a	82.7 b	148 b
Cyclaniliprole 50SL 1.6 L	230 bc	43% a	24.2 c	43 c
Exirel® 1.49 L	125 bcd	40% a	19.6 cd	35 cd
Mycotrol® ESO 2.34 L	111 bcd	52% a	8.3 cd	15 cd
Vydate® 2L 4.68 L	589 a	26% a	124.4 a	223 a

[1]Active ingredients of the commercial products listed are: Venerate = heat killed *Burkholderia* spp. strain A396 cells and spent fermentation media 94.46%; Warrior = Lambda-cyhalothrin (22.8%); Grandevo = *Chromobacterium subtsugae* strain PRAA4 1T and spent fermentation media 30.0%; Avaunt = indoxacarb (30%); Apta = tolfenpyrad (15%); cyclaniliprole = IKI-3106 50SL ISK Biosciences experimental product; Exirel = cyantraniliprole (10.2%); Mycotrol = *Beauvaria bassianna* GHA (11.3%); Vydate = oxamyl (42%).

[2]Means within columns followed by the same letter are not significantly different (LSD, $P < 0.05$).

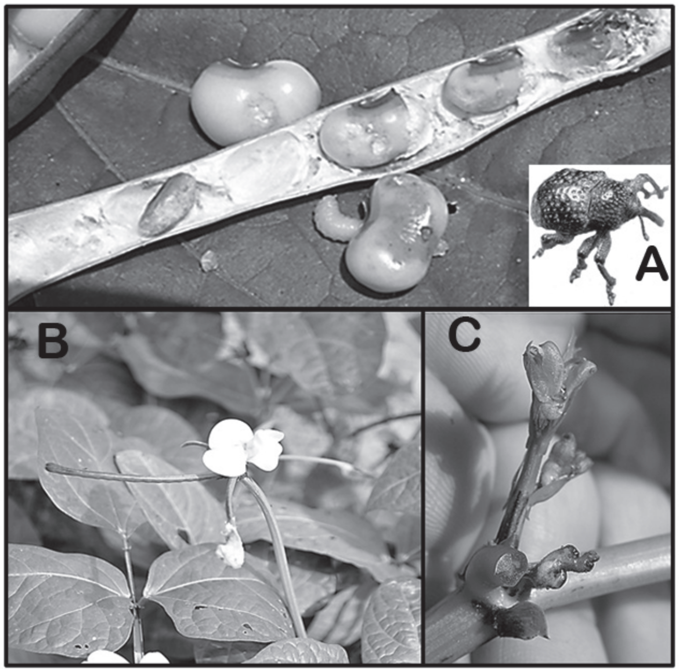

Fig. 2. Photographic collage of (A) *Chalcodermus aeneus* Boheman adult, larvae, and damage to fresh cowpea seed, (B) normal cowpea flower and fruit structure, and (C) damaged peduncle (in an adjacent plot to the flowering plants in image C) which resulted in > 95% loss of floral development in the non-insecticide treated plots in Test 2 at the Lang-Rigdon Farm, Tifton, Georgia, USA, in 2016.

biological control of cowpea curculio reported by Capinera (2001) is not sufficient for rescue treatments, as in Test 2 (Table 2). Even though biological control of adults on the foliage is not likely to be adequate, control of the curculio in the soil phase, especially for overwintering populations, has shown more promise (Riley, unpublished data) but is still very much in the development stage. We believe that cowpea curculio management needs to be at the population level, preferably involving eradication of the pest on a regional scale, as has been done with the boll weevil and other insect pests (El-Sayed et al. 2009).

Finally, the question that is perhaps most troubling is whether or not *C. aeneus* has the potential for movement to, and establishment in, other parts of the world. Given the estimated > 8 million metric tons of dry cowpea produced worldwide, mostly in Africa (Anonymous 2016), and the stated severity of this pest, this is not a New World weevil that anyone would ever want to be introduced into the African continent. Fortunately, the reproductive biology of *C. aeneus* is such that it requires both green cowpea pods for larval development, and a soil phase for pupation and adult emergence (Arant 1938). To put this in perspective, it is useful to compare 3 weevil species in terms of their potential for spread via worldwide shipments (Fig. 3). True stored grain species like the cowpea weevil, *Callosobruchus maculatus* (Fabricius) (Coleoptera: Chrysomelidae), are easily transported in dried cowpea around the world at any time of yr and continue to reproduce in storage. Pepper weevil, *Anthonomus eugenii* Cano (Coleoptera: Curculionidae), can be shipped only in green pepper pods that have escaped being graded out before shipment, and only when fresh pepper markets are receiving from a pepper weevil-infested region. Pepper weevil does not survive multiple d of freezing, and only reproduces on *Capsicum* and *Solanum* (both Solanaceae) species, so even if shipped, it may not become established at the destination. *Chalcodermus aeneus*, by comparison, is much less likely to be shipped overseas, because by the time the grain is shipped, it is either dry or frozen (neither condition supports *C. aeneus* reproduction or survival). Thus, fortunately, this severe weevil pest of cowpea is not likely to be accidentally introduced into the Old World.

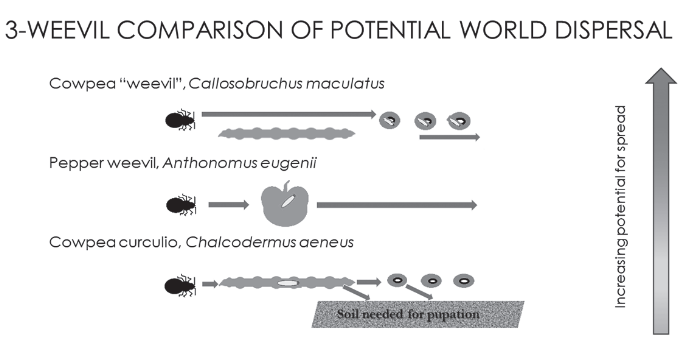

Fig. 3. Conceptual graphic illustrating the potential for movement of 3 weevil species in shipped crop fruit suggesting that stored grain pests such as *Callosobruchus maculatus* (Fabricius) are much more easily transported around the world than pepper weevil, *Anthonomus eugenii* Cano, in pepper or cowpea infested with *Chalcodermus aeneus* Boheman.

Acknowledgments

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References Cited

Ainslie GG. 1910. The cowpea curculio. USDA, Bureau of Entomology, Washington, DC, USA. Bulletin 85: Part VIII.

Anonymous. 1957. Soybeans, cowpea, and velvet beans, by states, 1924–53. USDA, Agricultural Marketing Service, Washington, DC, USA. Statistical Bulletin 211.

Anonymous. 2016. FAOSTAT. Rome, Italy. (online) http://faostat3.fao.org/browse/Q/QC/E (last accessed 17 Apr 2019).

Arant FS. 1938. Life history and control of the cowpea curculio. Alabama Polytechnic Institute, Agricultural Experiment Station, Auburn, Alabama, USA. Bulletin 246.

Boatright SR, McKissick JC. 2010. 2009 Georgia Farm Gate Value Report. Georgia Cooperative Extension Service, University of Georgia, Athens, Georgia, USA. Annual Report AR-10-01.

Capinera JL. 2001. Cowpea curculio, *Chalcodermus aeneus* Boheman (Coleoptera: Curculionidae), pp. 122–124 *In* Capinera J [ed.], Handbook of Vegetable Pests. Academic Press, San Diego, California, USA.

Chalfant RB. 1996. Insecticide resistance-management of permethrin and acephate against the cowpea curculio, *Chalcodermus aeneus* (Coleoptera: Curculionidae), a pest of the southern pea (*Vigna unguiculata* (L) Walp. International Journal of Pest Management 41: 249–254.

Chalfant RB. 1997. Management of the cowpea curculio *Chalcodermus aeneus* Boheman, a pest of the southern pea, *Vigna unguiculata* (L.) Walpers with varietal resistance and insecticides. New Development in Entomology 1997: 107–115.

Chambliss OL, Rymal KS. 1980. Pod-wall toughness as a measure of cowpea curculio resistance in southernpeas. HortScience 15: 418.

Coolong TS, Wright S, Ehlers J. 2012. Southernpea (Cowpea). University of Kentucky, Cooperative Extension Service, Lexington, Kentucky, USA. (online) http://www.uky.edu/ccd/sites/www.uky.edu.ccd/files/southernpea.pdf (last accessed 17 Apr 2019).

Fery RL, Cuthbert Jr FP. 1975. Inheritance of pod resistance to cowpea curculio infestation in southern peas. Journal of Heredity 66: 643–644.

Daoust RA, Roberts DW, das Neves BP. 1985. Distribution, biology and control of cowpea pests in Latin America, pp. 251–266 *In* Singh SR, Rachie KO [eds.], Cowpea Research, Production and Utilization. Wiley, New York, USA.

Dupree M, Beckham CM. 1955. The cowpea curculio, a pest of southern peas. Georgia Agricultural Experiment Stations, University of Georgia, Athens, Georgia, USA. Bulletin New Series 6.

El-Sayed AM, Suckling DM, Byers JA, Jang EB, Wearing CH. 2009. Potential of "lure and kill" in long-term pest management and eradication of invasive species. Journal of Economic Entomology 102: 815–835.

Ewansiha SU, Singh BB. 2006. Relative drought tolerance of important herbaceous legumes and cereals in the moist and semi-arid regions of West Africa. Journal of Food, Agriculture & Environment 4: 188–190.

Ferreira W. 2011. Southern peas for fresh market. Clemson Extension Service, Clemson University, Clemson, South Carolina, USA. (online) https://www.clemson.edu/extension/agribusiness/files/enterprise-budgets/southern-peas.pdf (last accessed 17 Apr 2019).

Hall AE, Frate CA. 1996. Blackeye bean production in California. University of California, Division of Agriculture and Natural Resources, Davis, California, USA. Publication 21518.

Maes J-M, O'Brien CW. 1990. Lista anotada de los Curculionoidea (Coleoptera) de Nicaragua. Revista Nicaragüense de Entomología 12: 1–78.

Ng NQ, Marechal R. 1985. Cowpea taxonomy, origin and germplasm, pp. 11–21 *In* Singh SR, Rachie KO [eds.], Cowpea Research, Production and Utilization. Wiley, New York, USA.

N'Guessan KF, Chalfant RB. 1990. Dose response of the cowpea curculio (Coleoptera: Curculionidae) from different regions of Georgia to some currently used pyrethroid insecticides. Journal of Entomological Science 25: 219–222.

Nilakhe SS, Chalfant RB, Singh SV. 1981. Evaluation of southern green stink bug damage to cowpea. Journal of Economic Entomology 74: 589–592.

Quinn J, Meyers R. 2002. Cowpea: a versatile legume for hot, dry conditions. Alternative Crop Guide. Jefferson Institute, Washington, DC, USA. (online) https://hort.purdue.edu/newcrop/articles/ji-cowpea.html (last accessed 23 Apr 2019).

Riley DG, Kicklighter J, Sparks Jr AN. 2015. Sampling of the cowpea curculio, *Chalcodermus aeneus*, with traps in southern peas. Crop Protection 67: 72–76.

SAS Institute. 2003. User's manual, version 9.1, SAS Institute, Cary, North Carolina, USA.

TenEyck AM, Call LE. 1909. Cow-peas. Kansas State Agricultural College Experiment Station, Kansas State University, Manhattan, Kansas, USA. Bulletin 160.

Timko MP, Singh BB. 2008. Cowpea, a multifunctional legume, pp. 227–258 *In* Moore PH, Ming R [eds.], Genomics of Tropical Plants. Springer, Dordrecht, The Netherlands.

Wight WF. 1907. The history of the cowpea and its introduction into America, pp. 43–59 *In* USDA, Bureau of Plant Industries, Washington, DC, USA. Bulletin 102.

Wolfe K, Stubbs K. 2015. 2014 Georgia Farm Gate Value Report. Georgia Cooperative Extension Service, University of Georgia, Athens, Georgia, USA. Annual Report AR-15-01.