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Recommendations

Examples of Risk Tools for Pests in Peanut (*Arachis hypogaea*) Developed for Five Countries Using Microsoft Excel

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Abstract

Suppressing pest populations below economically-damaging levels is an important element of sustainable peanut (*Arachis hypogaea* L.) production. Peanut farmers and their advisors often approach pest management with similar goals regardless of where they are located. Anticipating pest outbreaks using field history and monitoring pest populations are fundamental to protecting yield and financial investment. Microsoft Excel was used to develop individual risk indices for pests, a composite assessment of risk, and costs of risk mitigation practices for peanut in Argentina, Ghana, India, Malawi, and North Carolina (NC) in the United States (US). Depending on pests and resources available to manage pests, risk tools vary considerably, especially in the context of other crops that are grown in sequence with peanut, cultivars, and chemical inputs. In Argentina, India, and the US where more tools (e.g., mechanization and pesticides) are available, risk indices for a wide array of economically important pests were developed with the assumption that reducing risk to those pests likely will impact peanut yield in a positive manner. In Ghana and Malawi where fewer management tools are available, risks to yield and aflatoxin contamination are presented without risk indices for individual pests. The Microsoft Excel platform can be updated as new and additional information on effectiveness of management practices becomes apparent. Tools can be developed using this platform that are appropriate for their geography, environment, cropping systems, and pest complexes and management inputs that are available. In this article we present examples for the risk tool for each country.

Key words: agronomy, crop rotation, cultivar resistance, decision tool, IPM-Agriculture, pesticide

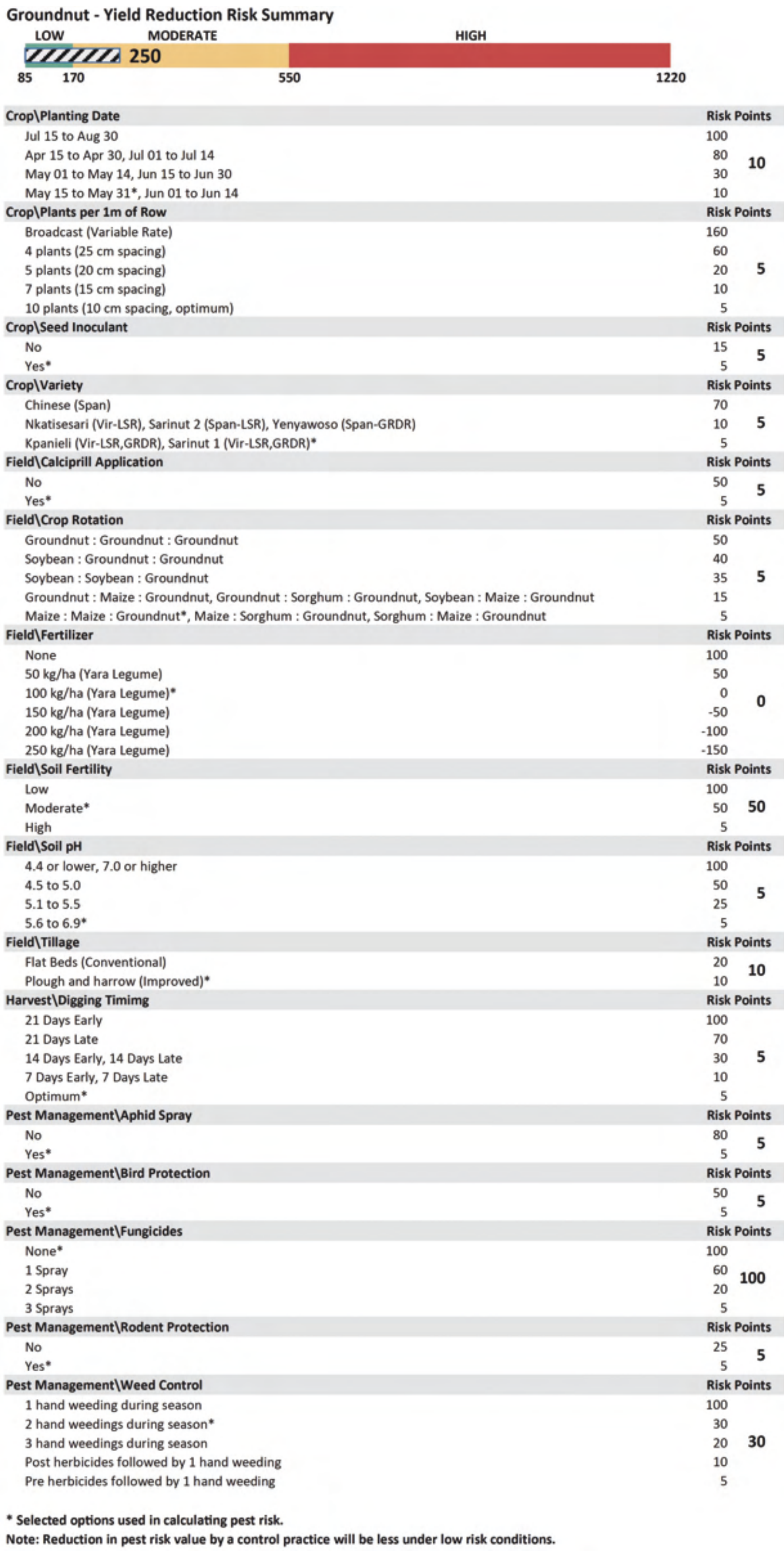
Groundnut - Aflatoxin Risk Summary

	Risk Points	
Crop\Planting Date	**Risk Points**	**20**
Apr 15 to Apr 30, Jul 15 to Aug 30	100	
Jul 01 to Jul 14	80	
Jun 15 to Jun 30	40	
May 01 to May 14, May 15 to May 31*, Jun 01 to Jun 14	20	
Crop\Plants per 1m of Row	**Risk Points**	**5**
Broadcast (Variable Rate)	60	
4 plants (25 cm spacing)	20	
5 plants (20 cm spacing)	15	
7 plants (15 cm spacing)	10	
10 plants (10 cm spacing, optimum)	5	
Crop\Seed Inoculant	**Risk Points**	**5**
No	25	
Yes*	5	
Crop\Variety	**Risk Points**	**15**
Chinese (Span), Sarinut 1 (Vir-LSR,GRDR)*	15	
Kpanieli (Vir-LSR,GRDR), Nkatisesari (Vir-LSR), Sarinut 2 (Span-LSR), Yenyawoso (Span-GRDR)	5	
Field\Calciprill Application	**Risk Points**	**5**
No	100	
Yes*	5	
Field\Crop Rotation	**Risk Points**	**5**
Groundnut : Groundnut : Groundnut	80	
Soybean : Groundnut : Groundnut	60	
Groundnut : Maize : Groundnut, Groundnut : Sorghum : Groundnut, Soybean : Maize : Groundnut	50	
Soybean : Soybean : Groundnut	40	
Maize : Maize : Groundnut*, Maize : Sorghum : Groundnut, Sorghum : Maize : Groundnut	5	
Field\Fertilizer	**Risk Points**	**15**
None	80	
50 kg/ha (Yara Legume)	40	
100 kg/ha (Yara Legume)*	15	
150 kg/ha (Yara Legume), 200 kg/ha (Yara Legume), 250 kg/ha (Yara Legume)	5	
Field\Soil Fertility	**Risk Points**	**0**
Low	20	
Moderate*	0	
High	-20	
Field\Soil pH	**Risk Points**	**5**
4.4 or lower, 7.0 or higher	50	
4.5 to 5.0	30	
5.1 to 5.5	20	
5.6 to 6.9*	5	
Field\Tillage	**Risk Points**	**10**
Flat Beds (Conventional)	20	
Plough and harrow (Improved)*	10	
Harvest\Digging Timimg	**Risk Points**	**20**
21 Days Early, 21 Days Late	150	
14 Days Late	120	
14 Days Early	80	
7 Days Early, 7 Days Late	30	
Optimum*	20	
Harvest\Drying	**Risk Points**	**10**
Ground	160	
Cemented floor	50	
Tarpulin*	10	
Pest Management\Aphid Spray	**Risk Points**	**5**
No	10	
Yes*	5	
Pest Management\Bird Protection	**Risk Points**	**5**
No	25	
Yes*	5	
Pest Management\Fungicides	**Risk Points**	**60**
None*	60	
1 Spray	40	
2 Sprays	20	
3 Sprays	5	
Pest Management\Rodent Protection	**Risk Points**	**5**
No	20	
Yes*	5	
Pest Management\Weed Control	**Risk Points**	**20**
1 hand weeding during season, 3 hand weedings during season	50	
2 hand weedings during season*, Post herbicides followed by 1 hand weeding	20	
Pre herbicides followed by 1 hand weeding	5	
Storage\Groundnut Moisture	**Risk Points**	**20**
Greater than 15%	80	
10 to 15%*	20	
Less than 10%	5	
Storage\Method	**Risk Points**	**20**
Traditional	160	
Sealed*	20	
Storage\Temperature	**Risk Points**	**20**
Higher than 32 °C	80	
28 to 32 °C	40	
Lower than 28 °C*	20	

*** Selected options used in calculating pest risk.**
Note: Reduction in pest risk value by a control practice will be less under low risk conditions.

Fig. 1. Risk summary for aflatoxin contamination in the northern Ghana peanut risk tool.

Peanut (*Arachis hypogaea* L.) is an important crop in many regions of the world and contributes to food security due to the resilience it adds in cropping systems and positive contributions to the human diet (Stalker et al. 2016, Valentine 2016). However, peanut is susceptible to a wide range of biotic and abiotic stresses that can limit yield and quality and create issues associated with food safety (Nigam et al. 2018, Jordan et al. 2018) . Low yield and poor quality can affect financial sustainability of peanut-based cropping systems. Employing cost-effective practices to minimize the impact of pests can increase peanut yield and financial sustainability. Research and



	Risk Points	
Crop\Planting Date	**Risk Points**	
Jul 15 to Aug 30	100	
Apr 15 to Apr 30, Jul 01 to Jul 14	80	**10**
May 01 to May 14, Jun 15 to Jun 30	30	
May 15 to May 31*, Jun 01 to Jun 14	10	
Crop\Plants per 1m of Row	**Risk Points**	
Broadcast (Variable Rate)	160	
4 plants (25 cm spacing)	60	
5 plants (20 cm spacing)	20	**5**
7 plants (15 cm spacing)	10	
10 plants (10 cm spacing, optimum)	5	
Crop\Seed Inoculant	**Risk Points**	
No	15	**5**
Yes*	5	
Crop\Variety	**Risk Points**	
Chinese (Span)	70	
Nkatisesari (Vir-LSR), Sarinut 2 (Span-LSR), Yenyawoso (Span-GRDR)	10	**5**
Kpanieli (Vir-LSR,GRDR), Sarinut 1 (Vir-LSR,GRDR)*	5	
Field\Calciprill Application	**Risk Points**	
No	50	**5**
Yes*	5	
Field\Crop Rotation	**Risk Points**	
Groundnut : Groundnut : Groundnut	50	
Soybean : Groundnut : Groundnut	40	
Soybean : Soybean : Groundnut	35	**5**
Groundnut : Maize : Groundnut, Groundnut : Sorghum : Groundnut, Soybean : Maize : Groundnut	15	
Maize : Maize : Groundnut*, Maize : Sorghum : Groundnut, Sorghum : Maize : Groundnut	5	
Field\Fertilizer	**Risk Points**	
None	100	
50 kg/ha (Yara Legume)	50	
100 kg/ha (Yara Legume)*	0	**0**
150 kg/ha (Yara Legume)	-50	
200 kg/ha (Yara Legume)	-100	
250 kg/ha (Yara Legume)	-150	
Field\Soil Fertility	**Risk Points**	
Low	100	
Moderate*	50	**50**
High	5	
Field\Soil pH	**Risk Points**	
4.4 or lower, 7.0 or higher	100	
4.5 to 5.0	50	**5**
5.1 to 5.5	25	
5.6 to 6.9*	5	
Field\Tillage	**Risk Points**	
Flat Beds (Conventional)	20	**10**
Plough and harrow (Improved)*	10	
Harvest\Digging Timimg	**Risk Points**	
21 Days Early	100	
21 Days Late	70	
14 Days Early, 14 Days Late	30	**5**
7 Days Early, 7 Days Late	10	
Optimum*	5	
Pest Management\Aphid Spray	**Risk Points**	
No	80	**5**
Yes*	5	
Pest Management\Bird Protection	**Risk Points**	
No	50	**5**
Yes*	5	
Pest Management\Fungicides	**Risk Points**	
None*	100	
1 Spray	60	**100**
2 Sprays	20	
3 Sprays	5	
Pest Management\Rodent Protection	**Risk Points**	
No	25	**5**
Yes*	5	
Pest Management\Weed Control	**Risk Points**	
1 hand weeding during season	100	
2 hand weedings during season*	30	
3 hand weedings during season	20	**30**
Post herbicides followed by 1 hand weeding	10	
Pre herbicides followed by 1 hand weeding	5	

*** Selected options used in calculating pest risk.**
Note: Reduction in pest risk value by a control practice will be less under low risk conditions.

Fig. 2. Risk summary for yield in the northern Ghana peanut risk tool.

educational programs by the public institutions, the private sector, and nongovernmental organizations often provide solutions to pests that adversely affect the peanut crop. Many of these solutions are developed locally with an understanding of the financial impact of pests and use of interventions that are available and economically practical.

Even though effective strategies and tools are available to suppress pests in peanut, information about those strategies is often

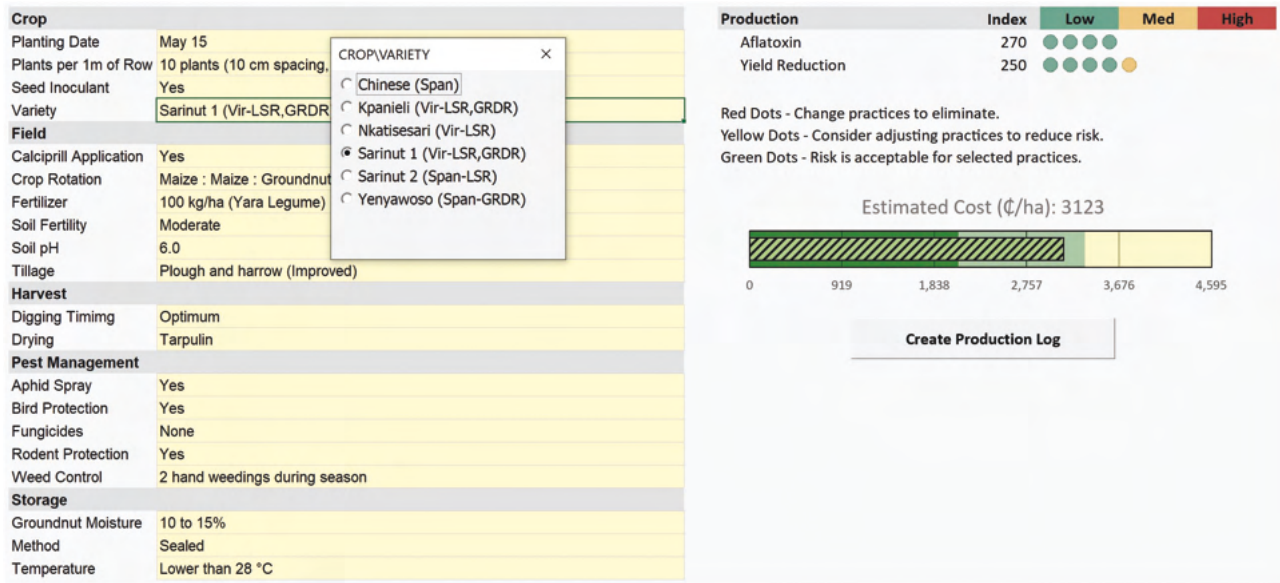


Fig. 3. Drop down menu for varieties in the northern Ghana peanut risk tool.

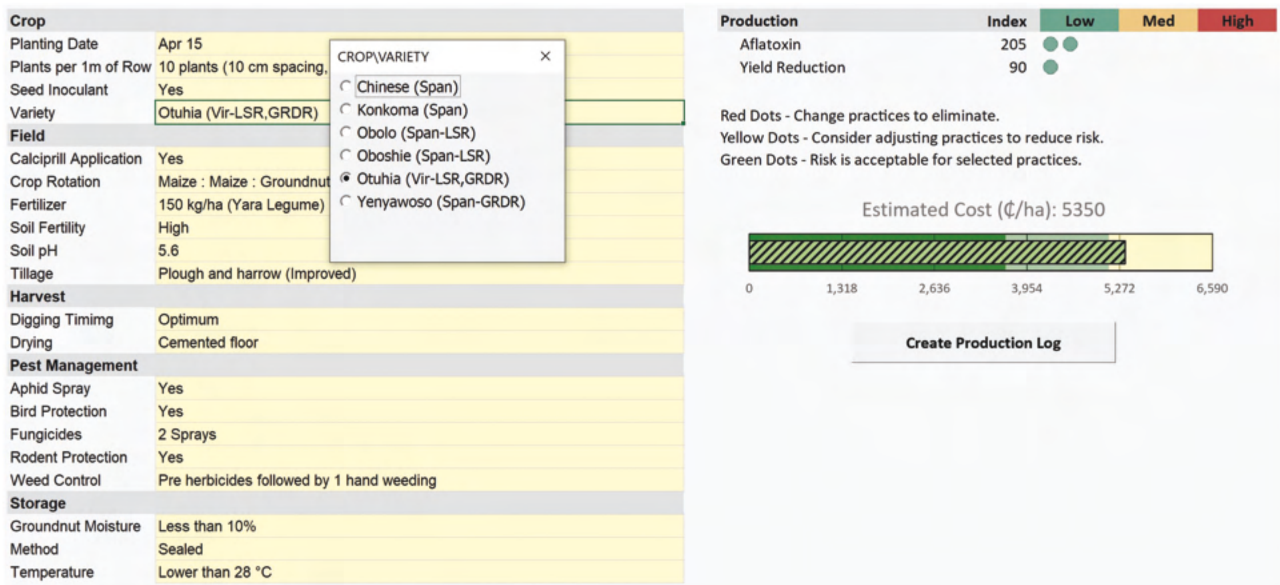


Fig. 4. Drop down menu for varieties in major season in the southern Ghana peanut risk tool.

presented for individual disciplines (e.g., entomology, plant pathology, nematology, and weed science). In some instances practitioners are required to search through resources to determine interaction across pest disciplines in order to develop a holistic approach to pest management. Several approaches have been developed to address this challenge. In the southeastern region of the US, the Peanut Rx guide allows growers and their advisors to determine the impact of production and pest management practices on tomato spotted wilt (tospovirus, Bunyaviridae) transmitted by thrips (*Frankliniella fusca* Pergande, *F. occidentalis* Hinds) and other pathogens in peanut (Anonymous 2022). In North Carolina in the United States, a Microsoft Excel platform was developed to assess overall risk from production and pest management practices for thirteen pests or groups of pests commonly found in peanut (Jordan et al. 2022). Outside of these educational resources, there are no electronic resources in other countries for peanut that allow the research and education community and practitioners to easily assess the composite risk based on strategies that are planned for a particular field and cropping cycle across several disciplines. An electronic tool that enables farmers and their advisors to assess overall risk with different practices in a more effective manner could potentially result in greater protection of yield and increased financial sustainability.

In NC, a Microsoft Excel platform was designed to allow farmers and their advisors (e.g., private crop consultants, extension agents, agribusiness, nongovernmental organizations, and Federal and State agencies) to identify risk from a set of practices based on field history (Jordan et al. 2022). The platform computes cost of each set of practices so that farmers can observe the financial impact of changes in practices designed to reduce risk. A data log function is also a part

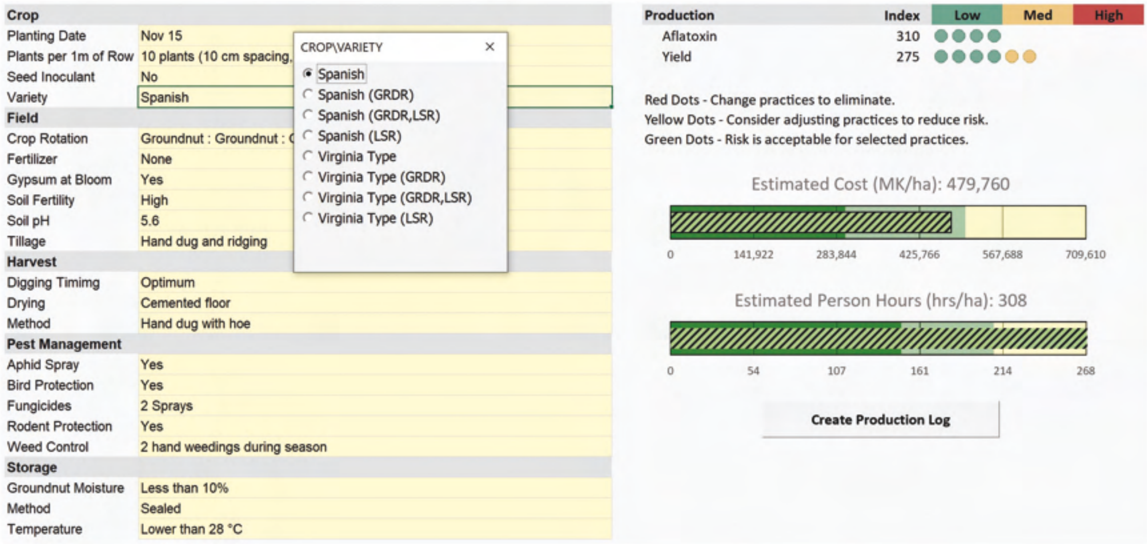


Fig. 5. Drop down menu for varieties in the Malawi peanut risk tool.

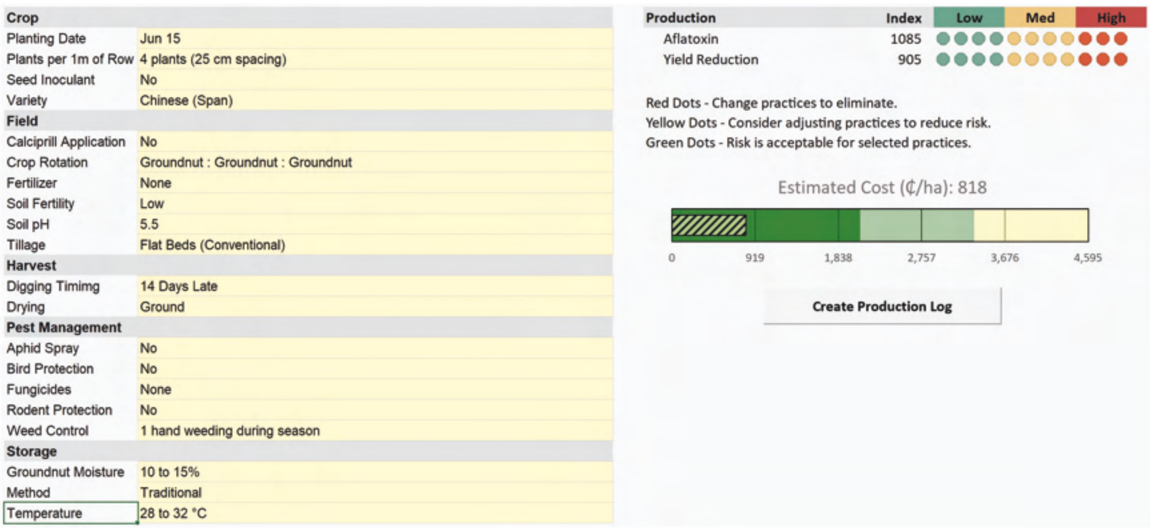


Fig. 6. Risk to aflatoxin contamination, yield, and cost of production for the limited input system in the northern Ghana peanut risk tool.

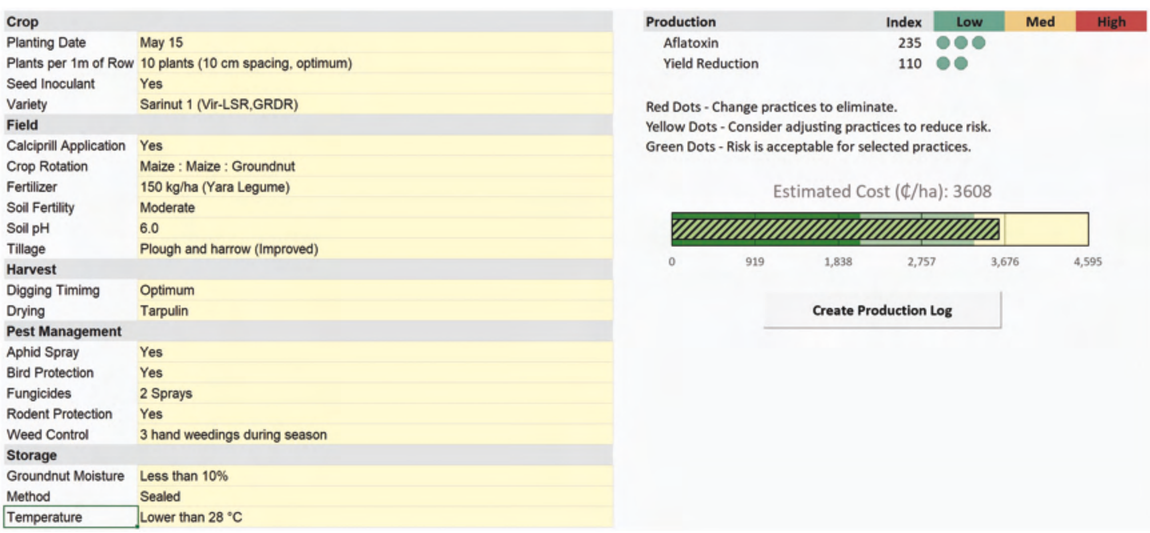


Fig. 7. Risk to aflatoxin contamination, yield, and cost of production for the high input system in the northern Ghana peanut risk tool.

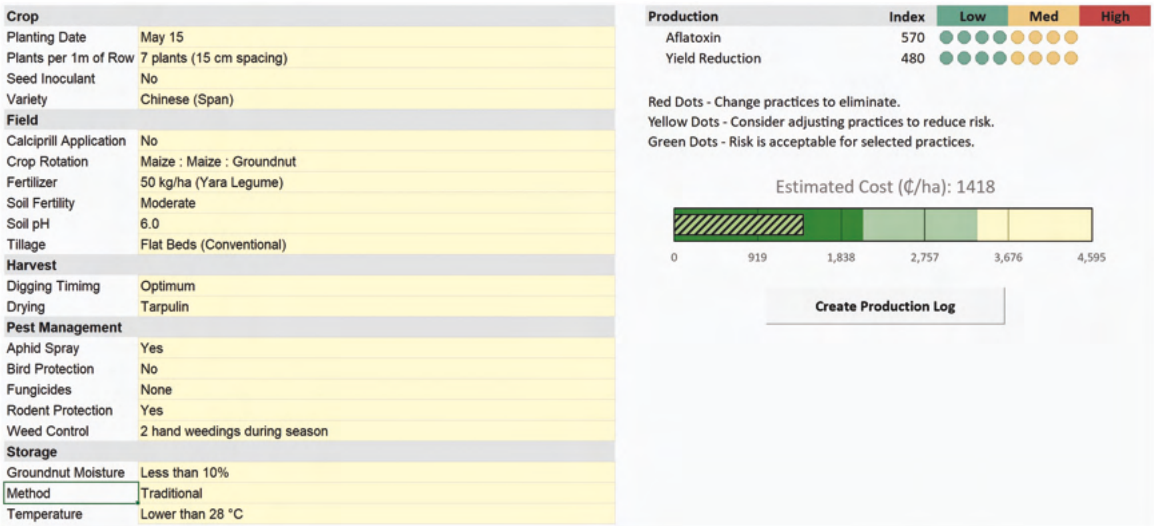


Fig. 8. Risk to aflatoxin contamination, yield, and cost of production for the medium input system in the northern Ghana peanut risk tool.

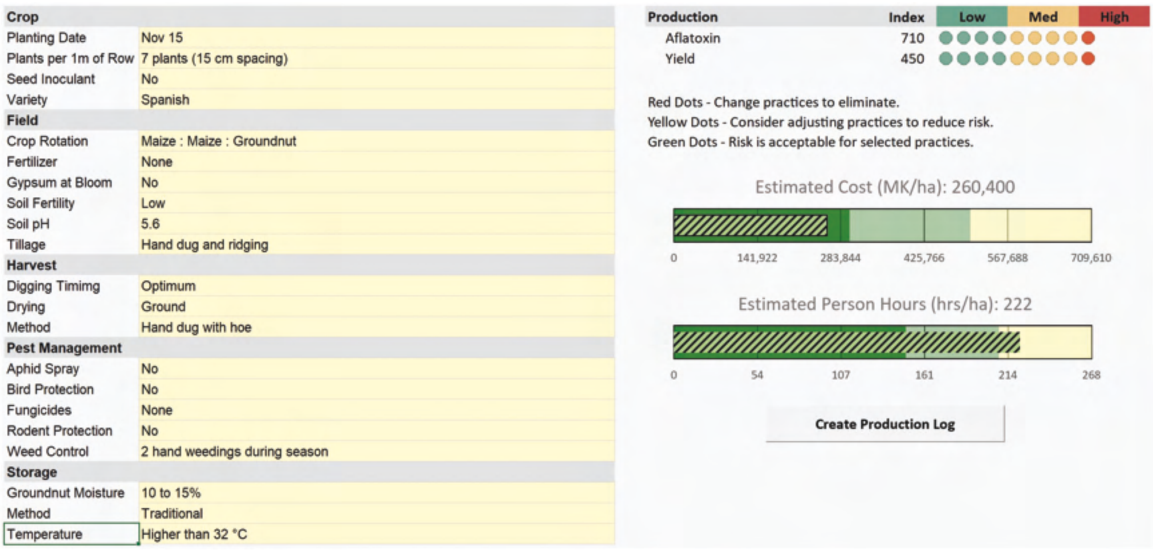


Fig. 9. Risk to aflatoxin contamination, yield, and cost of production for the limited input system in the Malawi peanut risk tool.

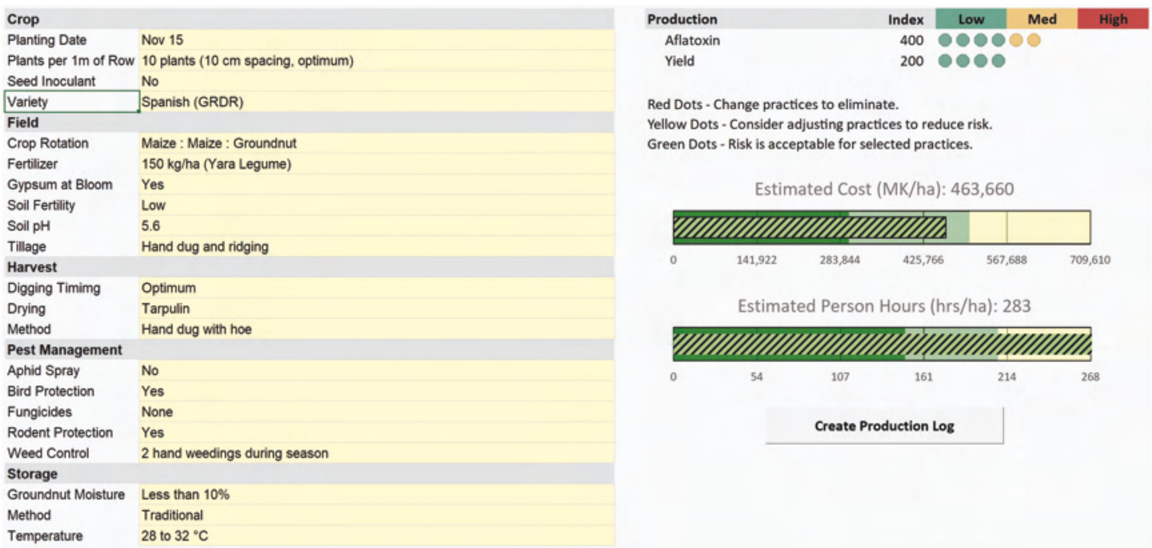


Fig. 10. Risk to aflatoxin contamination, yield, and cost of production for the high input system in the Malawi peanut risk tool.

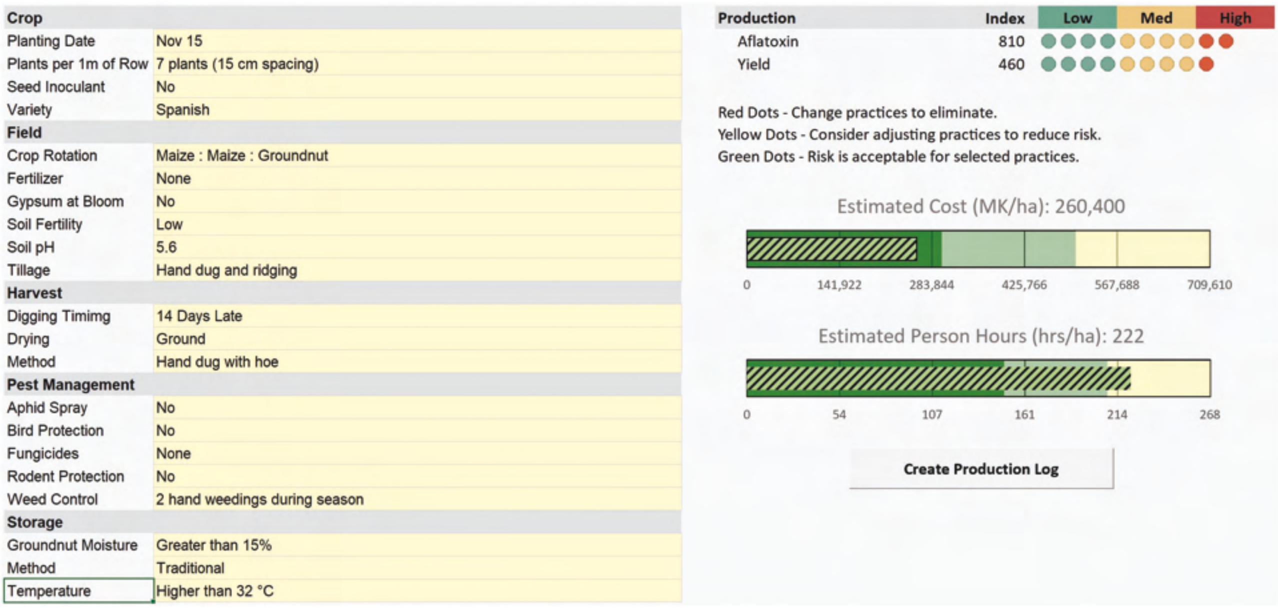


Fig. 11. Influence of timing of digging, drying method, and approaches to storage on aflatoxin contamination, yield, and cost of production in Malawi peanut risk tool with poor practices.

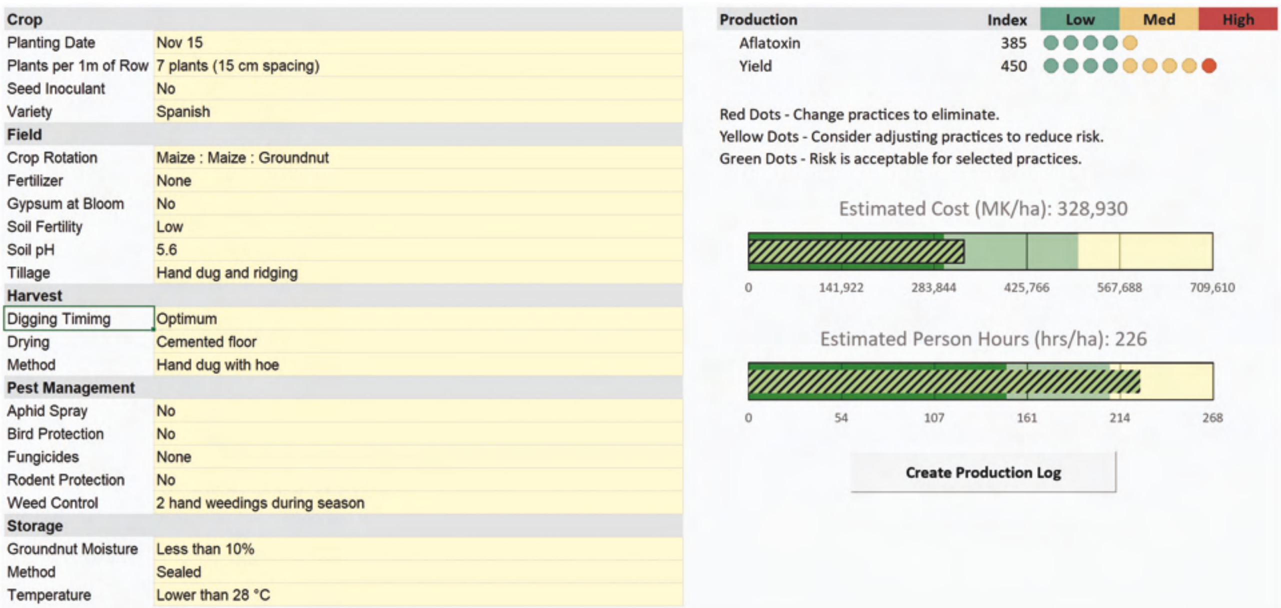


Fig. 12. Influence of timing of digging, drying method, and approaches storage on aflatoxin contamination, yield, and cost of production in Malawi peanut risk tool with improved practices.

of the platform that enables the user to electronically record production and pest management practices for the field and other important factors including yield, market grade characteristics, and rainfall. A detailed description of the NC peanut risk tool and examples of pests and pest management interactions are provided elsewhere (Jordan et al. 2022). When the NC peanut risk tool was under development, the decision to use Microsoft Excel as the platform was made so that tools for other states in the US or other countries could use the platform to create their own risk management tool. A portion of the funding for the development of the NC peanut risk tool was from the USAID Feed the Future Innovation Lab for Peanut with a specific goal of creating a tool that was transferable to partnering countries and ultimately a risk management tool that is available for the general public. In this paper, we provide examples of Microsoft Excel based peanut risk tools developed for Argentina, Ghana, India, and Malawi using the peanut risk tool initially developed for NC. The current iteration of each of these tools, a blank template, and an instructional video for creation of a risk tool can be found at: https://cropmanagement.cals.ncsu.edu/risk-tools/peanut.html.

Peanut Risk Tools in Ghana and Malawi

The peanut risk tools for Ghana and Malawi were developed simultaneously with information from both countries exchanged among scientists and practitioners. Risk to yield and contamination by aflatoxin (produced by *Aspergillus flavus* and *A. parasiticus*)

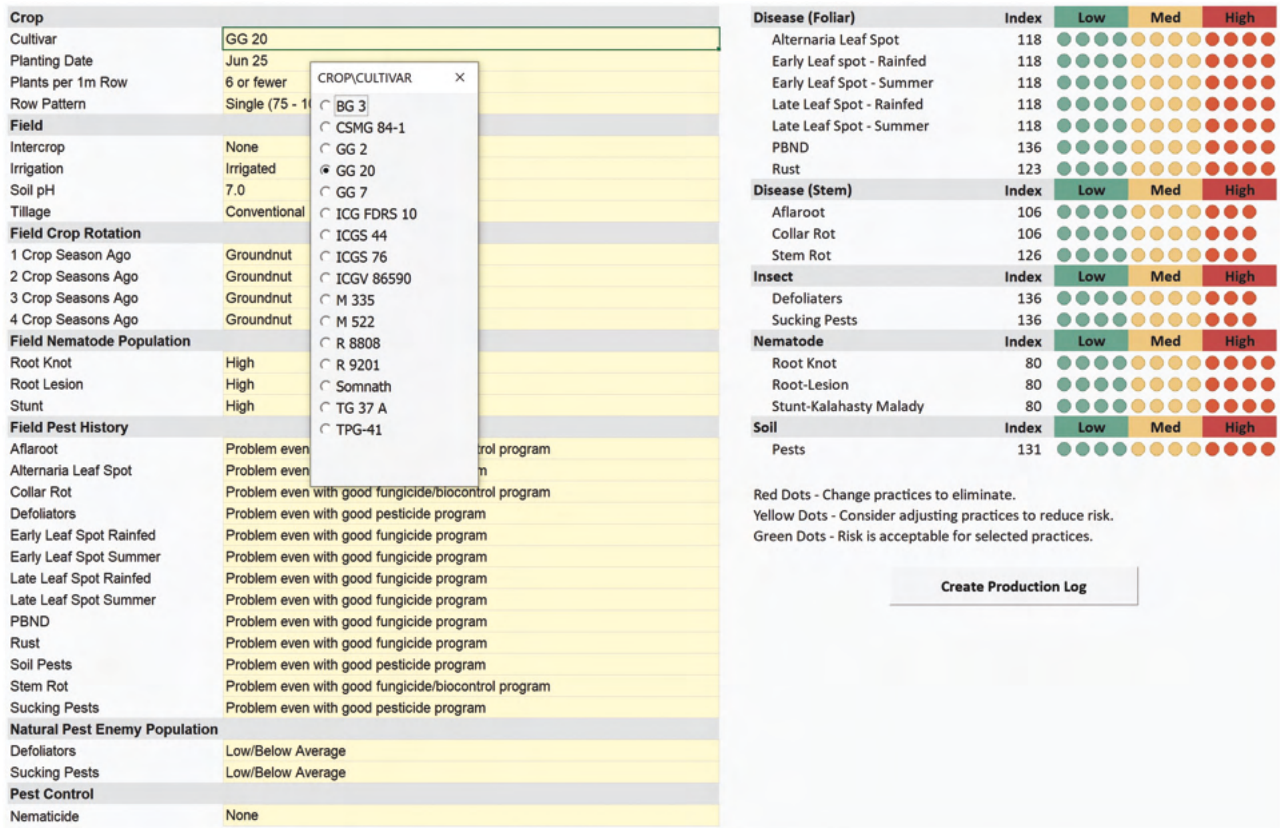


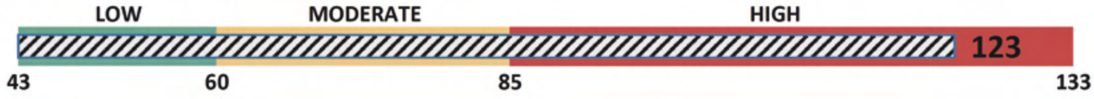
Fig. 13. Drop down menu for varieties in India peanut risk tool.

were compared using information for five categories of practices. Examples of the components of the northern Ghana peanut risk tool are presented in Figs. 1 and 2. The risk tools differed between the countries primarily in areas of cultivar selection, planting patterns and plant population, and planting dates. Also, peanut production in Ghana is impacted by a bimodal rainfall pattern in southern Ghana and a unimodal rainfall pattern in northern Ghana. Malawi has a single production season similar to northern Ghana. Risk tools in Ghana and Malawi include estimates of production and pest management costs. The Malawi risk tool also includes estimates of the time required to complete tasks (e.g., labor costs in person hours). Cultivar selection is a major driver of yield and is an important element of risk tools in Ghana and Malawi. Drop down menus for cultivar selection for both risk tools in Ghana (unimodal and bimodal rainfall seasons) and the risk tool in Malawi are presented in Figs. 3–5.

Risk to yield and aflatoxin contamination for three levels of input for northern Ghana are contrasted in Figs. 6–8. When inputs are limited, risk to both yield and aflatoxin are high as noted with three dots in the red category for both parameters (Fig. 6). This approach to peanut production in many areas of Ghana is not uncommon where availability of interventions are limited and financial constraints exist (e.g., financial credit and access to loans) (Abudulai et al. 2020, Appaw et al. 2020). Estimated cost of production for this low input system was $131/ha (818 Ghana cedes/ha). When resources are available and interventions are included across all categories, risk to yield and contamination by aflatoxin was essentially eliminated but at a cost that is over four times the cost of the low input system ($577/ha or 3,608 Ghana cedes/ha) (Fig. 7). Few peanut farmers in Ghana have access to all interventions and/or financing to purchase available resources prior to the cropping cycle. A reasonable alternative to both the low and high input systems is presented in Fig. 8. Risk in this scenario remains relatively high (e.g., yellow dots for yield and aflatoxin) but with lower costs at $226/ha (1,418 Ghana cedes/ha). Although cost is greater than the low input system, risk to yield and aflatoxin is lowered considerably compared with the low input system.

The Malawi peanut risk tool allows practitioners to observe not only changes in cost of production as risk is addressed but also gives an estimate of the labor involved as practices are modified. For example, cost of production when inputs are limited is $322/ha (260,400 Malawian kwacha/ha) with 222 person hours required in the limited input system (Fig. 9). In contrast, risk was lowered with increased inputs (e.g., fertilizer, gypsum, fungicide, and additional hand weeding) but required an increase to 283 person h/ha and a cost of $574/ha (463,660 Malawian kwacha/ha) (Fig. 10). The Malawi risk tool also demonstrates the value of adopting improved practices associated with digging peanut, drying, and storage to mitigate aflatoxin contamination (Figs. 11 and 12). Two red dots were present when peanut was dug 14 d after optimum pod maturity, dried on the ground to moisture exceeding 15%, and stored in a traditional setting at temperatures exceeding 32°C (Fig. 11). Risk was reduced to only one yellow dot when peanut was dug at optimum maturity, dried on cement flooring to less than 10% moisture, and stored in sealed bags at 28°C or lower (Fig. 12). Although not captured in this version of the Malawi risk tool, previous research (Appaw et al. 2020) reported that drying on tarps and storing in hermetically-sealed bags prevented increases in aflatoxin contamination during storage compared with traditional practices (e.g., drying on soil and storing in non-sealed bags) and also resulted in more higher quality

Groundnut - Rust Risk Summary



Crop\Cultivar	Risk Points	
GG 20*	30	
BG 3, CSMG 84-1, GG 2, GG 7, ICGS 44, ICGS 76, M 335, M 522, Somnath	20	**30**
ICG FDRS 10, ICGV 86590, R 8808, R 9201, TG 37 A, TPG-41	10	
Crop\Planting Date	**Risk Points**	
Jun 20 to Dec 31*	10	**10**
Jan 01 to Jun 19	5	
Field\Intercrop	**Risk Points**	
Cluster Bean, Cotton, Maize, Pearl Millet, Pulses, Sorghum	15	**5**
None*	5	
Field\Irrigation	**Risk Points**	
Irrigated (Recommended), Irrigated*	15	**15**
Non-Irrigated	5	
Field\Tillage	**Risk Points**	
Conventional*, Deep (Improved)	15	**15**
Strip into killed cover crop or previous crop residue	5	
Field Crop Rotation\1 Crop Season Ago	**Risk Points**	
Groundnut*	15	**15**
Chickpea, Cotton, Cumin, Fodder, Garlic, Melons, Onion, Pearl Millet, Vegetables, Wheat	3	
Field Crop Rotation\2 Crop Seasons Ago	**Risk Points**	
Groundnut*	10	**10**
Chickpea, Cotton, Cumin, Fodder, Garlic, Melons, Onion, Pearl Millet, Vegetables, Wheat	2	
Field Crop Rotation\3 Crop Seasons Ago	**Risk Points**	
Groundnut*	5	**5**
Chickpea, Cotton, Cumin, Fodder, Garlic, Melons, Onion, Pearl Millet, Vegetables, Wheat	2	
Field Crop Rotation\4 Crop Seasons Ago	**Risk Points**	
Groundnut*	3	**3**
Chickpea, Cotton, Cumin, Fodder, Garlic, Melons, Onion, Pearl Millet, Vegetables, Wheat	1	
Field Pest History\Rust	**Risk Points**	
Problem even with good fungicide program*	15	
Present but not a problem with good fungicide program	10	**15**
None (Groundnut never grown)	5	

*** Selected options used in calculating pest risk.**
Note: Reduction in pest risk value by a control practice will be less under low risk conditions.

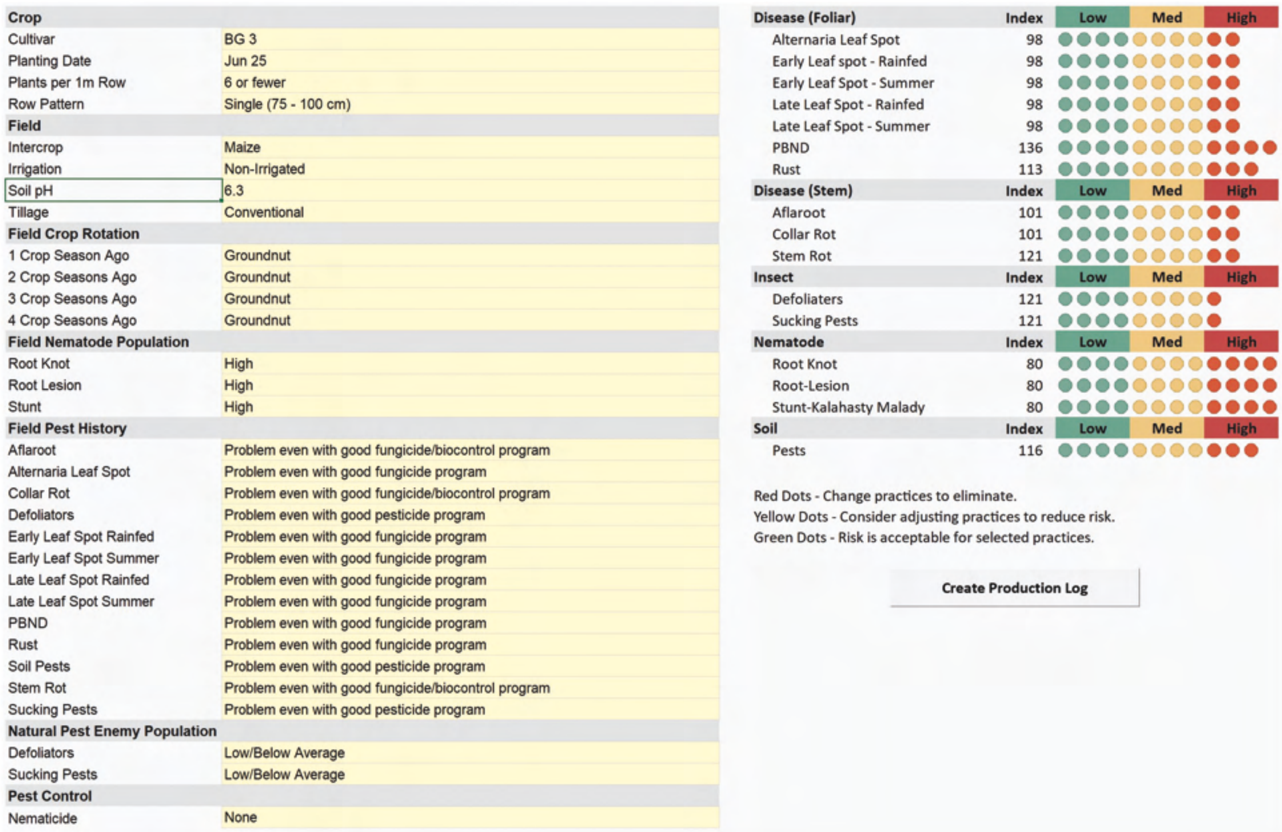
Fig. 14. Risk summary for rust in the India peanut risk tool.

kernels for the market. Less time and labor would be needed by the farmer because quality of peanut is at a higher level due to improved harvest, drying, and storage.

Argentina, India, and the United States

In contrast to Ghana and Malawi, farmers in Argentina, India, and NC (USA) have greater resources and inputs at their disposal to manage pests. While discussed in detail elsewhere, the NC risk tool includes individual risk indices for 13 pests or groups of pests and a wide range of pesticides available to suppress pest populations (Jordan et al. 2022). At the current time, risk tools for Argentina and India do not have cost of inputs. Improved cultivars are widely available for adoption as they are released because of a reliable certified seed delivery system. With the exception of tomato spotted wilt, a significant number of pesticides is available to suppress all pests that are economically important for peanut. However, cultural practices also contribute to suppression of pests.

The India peanut risk tool includes 16 pests or groups of pests under five categories (Fig. 13). A drop down menu for cultivars is presented in Fig. 13. Practices that affect rust (*Puccinia arachidis* Speg.) in peanut are presented in Fig. 14. When peanut was grown continuously and intercropped with corn (*Zea mays* L.) with limited inputs, risk was high (e.g., numerous red dots) for all pests (Fig. 15). In contrast, establishing a more effective rotation sequence with two cycles of cotton (*Gossypium hirsutum* L.), not intercropping, and planting a cultivar with resistance to this pathogen decreased risk substantially (Fig. 16). The current India peanut risk tool does not include the cost associated with production and pest management practices.



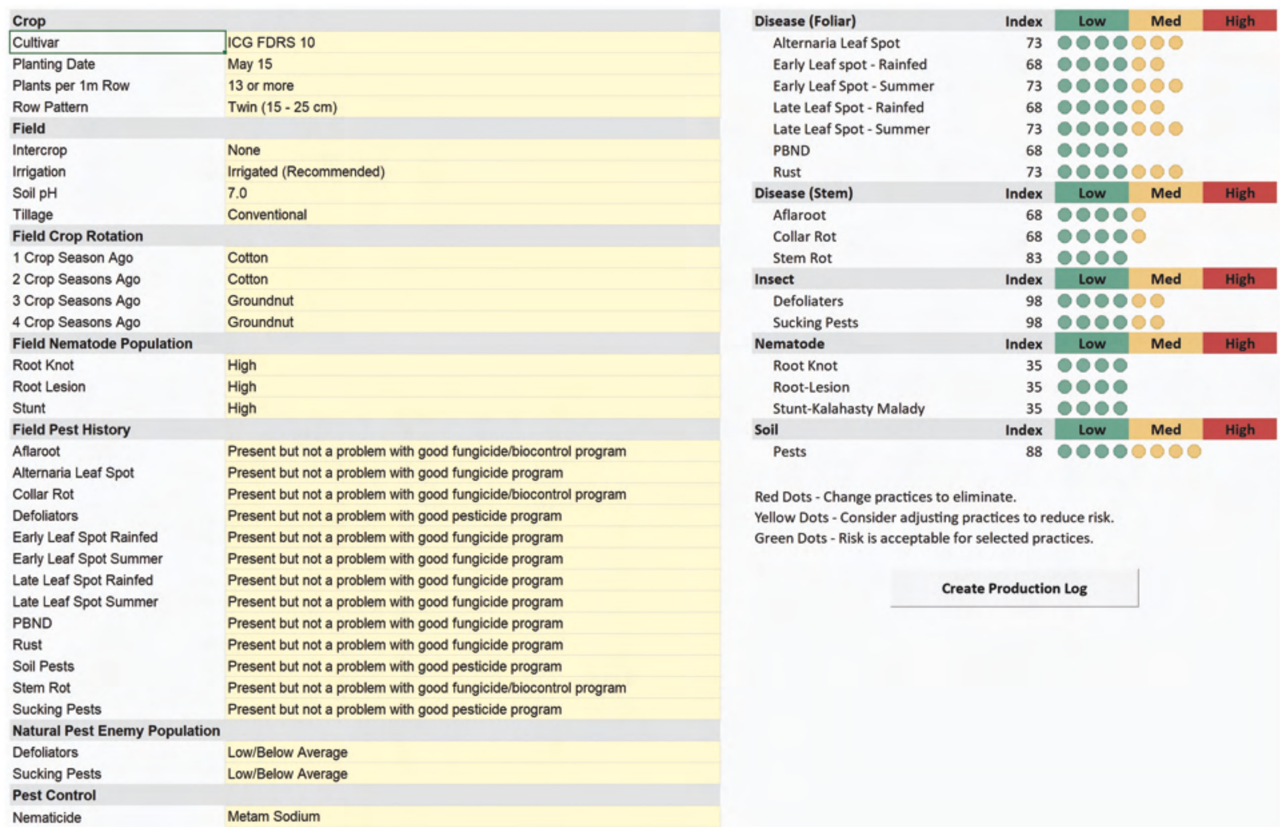
Crop	
Cultivar	BG 3
Planting Date	Jun 25
Plants per 1m Row	6 or fewer
Row Pattern	Single (75 - 100 cm)
Field	
Intercrop	Maize
Irrigation	Non-Irrigated
Soil pH	6.3
Tillage	Conventional
Field Crop Rotation	
1 Crop Season Ago	Groundnut
2 Crop Seasons Ago	Groundnut
3 Crop Seasons Ago	Groundnut
4 Crop Seasons Ago	Groundnut
Field Nematode Population	
Root Knot	High
Root Lesion	High
Stunt	High
Field Pest History	
Aflaroot	Problem even with good fungicide/biocontrol program
Alternaria Leaf Spot	Problem even with good fungicide program
Collar Rot	Problem even with good fungicide/biocontrol program
Defoliators	Problem even with good pesticide program
Early Leaf Spot Rainfed	Problem even with good fungicide program
Early Leaf Spot Summer	Problem even with good fungicide program
Late Leaf Spot Rainfed	Problem even with good fungicide program
Late Leaf Spot Summer	Problem even with good fungicide program
PBND	Problem even with good fungicide program
Rust	Problem even with good fungicide program
Soil Pests	Problem even with good pesticide program
Stem Rot	Problem even with good fungicide/biocontrol program
Sucking Pests	Problem even with good pesticide program
Natural Pest Enemy Population	
Defoliators	Low/Below Average
Sucking Pests	Low/Below Average
Pest Control	
Nematicide	None

Disease (Foliar)	Index	Low	Med	High
Alternaria Leaf Spot	98			
Early Leaf spot - Rainfed	98			
Early Leaf Spot - Summer	98			
Late Leaf Spot - Rainfed	98			
Late Leaf Spot - Summer	98			
PBND	136			
Rust	113			
Disease (Stem)	**Index**	**Low**	**Med**	**High**
Aflaroot	101			
Collar Rot	101			
Stem Rot	121			
Insect	**Index**	**Low**	**Med**	**High**
Defoliaters	121			
Sucking Pests	121			
Nematode	**Index**	**Low**	**Med**	**High**
Root Knot	80			
Root-Lesion	80			
Stunt-Kalahasty Malady	80			
Soil	**Index**	**Low**	**Med**	**High**
Pests	116			

Red Dots - Change practices to eliminate.
Yellow Dots - Consider adjusting practices to reduce risk.
Green Dots - Risk is acceptable for selected practices.

Create Production Log

Fig. 15. Risk from pests in the India peanut risk tool with limited inputs and practices.



Crop	
Cultivar	ICG FDRS 10
Planting Date	May 15
Plants per 1m Row	13 or more
Row Pattern	Twin (15 - 25 cm)
Field	
Intercrop	None
Irrigation	Irrigated (Recommended)
Soil pH	7.0
Tillage	Conventional
Field Crop Rotation	
1 Crop Season Ago	Cotton
2 Crop Seasons Ago	Cotton
3 Crop Seasons Ago	Groundnut
4 Crop Seasons Ago	Groundnut
Field Nematode Population	
Root Knot	High
Root Lesion	High
Stunt	High
Field Pest History	
Aflaroot	Present but not a problem with good fungicide/biocontrol program
Alternaria Leaf Spot	Present but not a problem with good fungicide program
Collar Rot	Present but not a problem with good fungicide/biocontrol program
Defoliators	Present but not a problem with good pesticide program
Early Leaf Spot Rainfed	Present but not a problem with good fungicide program
Early Leaf Spot Summer	Present but not a problem with good fungicide program
Late Leaf Spot Rainfed	Present but not a problem with good fungicide program
Late Leaf Spot Summer	Present but not a problem with good fungicide program
PBND	Present but not a problem with good fungicide program
Rust	Present but not a problem with good fungicide program
Soil Pests	Present but not a problem with good pesticide program
Stem Rot	Present but not a problem with good fungicide/biocontrol program
Sucking Pests	Present but not a problem with good pesticide program
Natural Pest Enemy Population	
Defoliators	Low/Below Average
Sucking Pests	Low/Below Average
Pest Control	
Nematicide	Metam Sodium

Disease (Foliar)	Index	Low	Med	High
Alternaria Leaf Spot	73			
Early Leaf spot - Rainfed	68			
Early Leaf Spot - Summer	73			
Late Leaf Spot - Rainfed	68			
Late Leaf Spot - Summer	73			
PBND	68			
Rust	73			
Disease (Stem)	**Index**	**Low**	**Med**	**High**
Aflaroot	68			
Collar Rot	68			
Stem Rot	83			
Insect	**Index**	**Low**	**Med**	**High**
Defoliaters	98			
Sucking Pests	98			
Nematode	**Index**	**Low**	**Med**	**High**
Root Knot	35			
Root-Lesion	35			
Stunt-Kalahasty Malady	35			
Soil	**Index**	**Low**	**Med**	**High**
Pests	88			

Red Dots - Change practices to eliminate.
Yellow Dots - Consider adjusting practices to reduce risk.
Green Dots - Risk is acceptable for selected practices.

Create Production Log

Fig. 16. Risk from pests in the India peanut risk tool with improved inputs and practices.

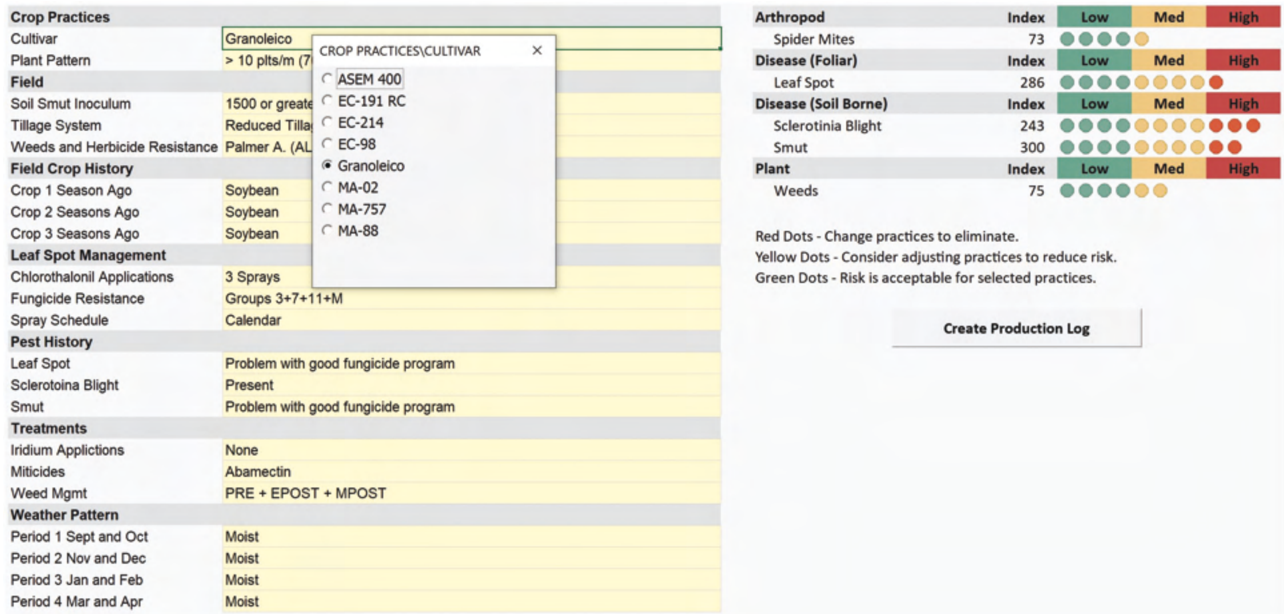


Fig. 17. Drop down menu for varieties in the Argentina peanut risk tool.

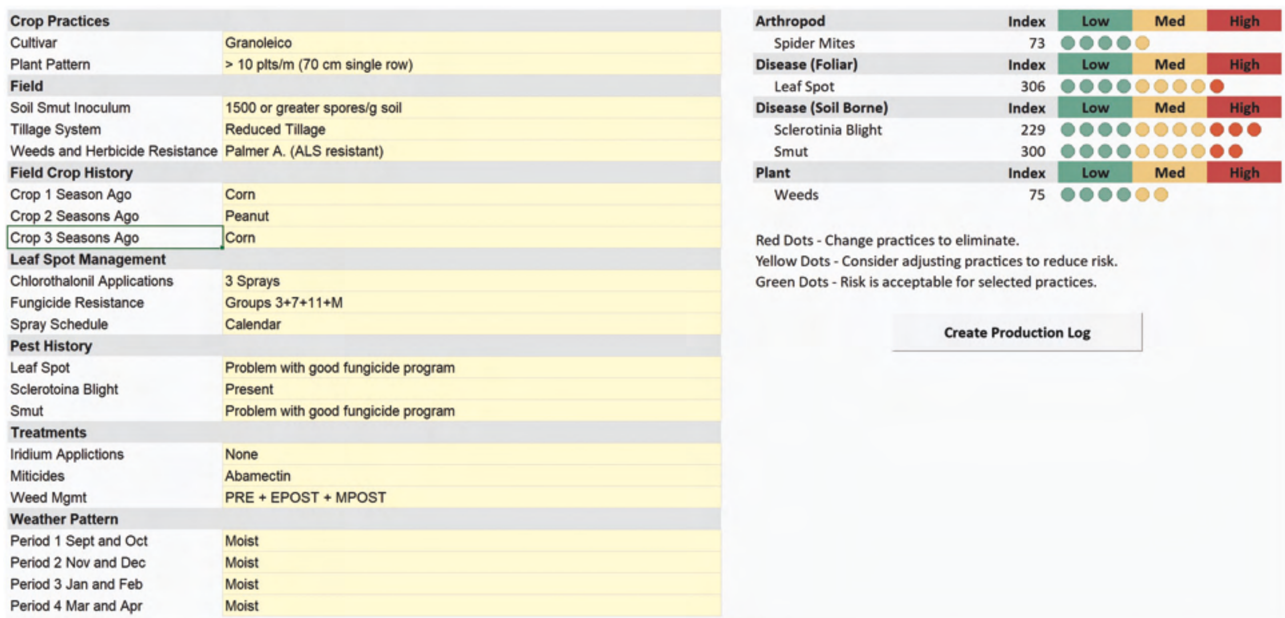


Fig. 18. High risk of smut disease in the Argentina peanut risk tool with short rotations and planting a cultivar without resistance to this disease.

The Argentina peanut risk tool includes indices for two-spotted spider mites (*Tetranychus urticae* Koch), peanut smut disease (caused by *Thecaphora frezii* Carranza and Lindquist), early leaf spot disease [caused by *Mycosphaerella arachidicola* W.A. Jenkins *(syn. Passalora arachidicola* W.A. Jenkins], late leaf spot disease [caused by *Nothopassalora personata* (Berk. & M.A. Curtis) U. Braun, C. Nakash., Videira & Crous], Sclerotinia blight (*Sclerotinia minor* Jagger), and weeds (Fig. 17). Eight cultivars are listed in the drop down menu for Argentina (Fig. 17). Similar to the India peanut risk tool, the current tool for Argentina does not include a cost comparison for management inputs. Risk to smut disease was high when the cultivar Granoleico was planted and the rotation prior to peanut was corn, peanut, and soybean [*Glycine max* (L.) Merr.] (Fig. 18). Adding one more year of corn prior to peanut and planting the cultivar EC-191 RC eliminated risk of smut disease (Fig. 19).

Similar to the NC peanut risk tool (Jordan et al. 2022), the Argentina peanut risk tool includes a drop down menu for resistance to fungicides with respect to leaf spot disease and herbicides (Figs. 20 and 21). Three scenarios associated with risk to two-spotted spider mites are presented in Figs. 22–24. Applying chlorothalonil (a broad spectrum and nonsystemic fungicide) three times during the season created greater risk for two-spotted spider mites compared with only one application of this fungicide (Fig. 22). Chlorothalonil and other fungicides can decrease presence of beneficial fungal pathogen *Entomophthora fresenii* Nowakowski, that adversely affects two-spotted spider mites in peanut, especially when moisture is limited (Carner and Canerday 1968, Campbell 1978). Chlorothalonil can also increase risk of Sclerotinia blight (Figs. 22 and 23) but is an effective fungicide for resistance management because it is a multi-site fungicides (Culbreath et al. 2002). Abamectin moderated risk to two-spotted mites (Fig. 24).

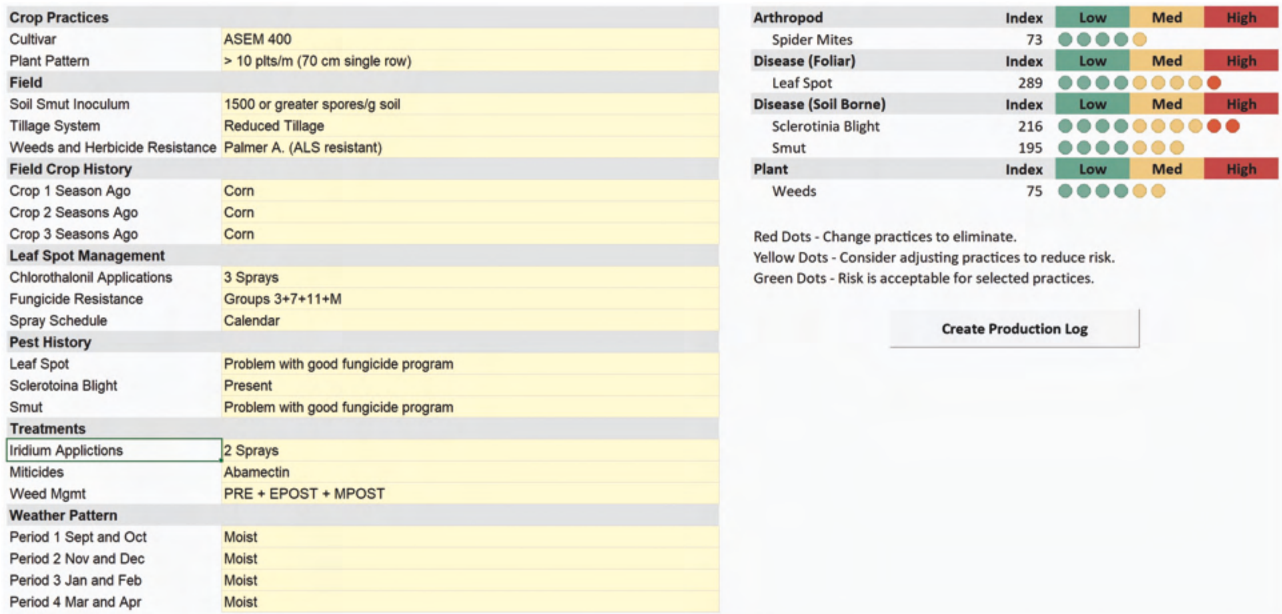


Fig. 19. Risk of smut disease in the Argentina peanut risk tool when the number of years between peanut plantings is increased, a smut tolerant variety is planted, and iridium is applied.

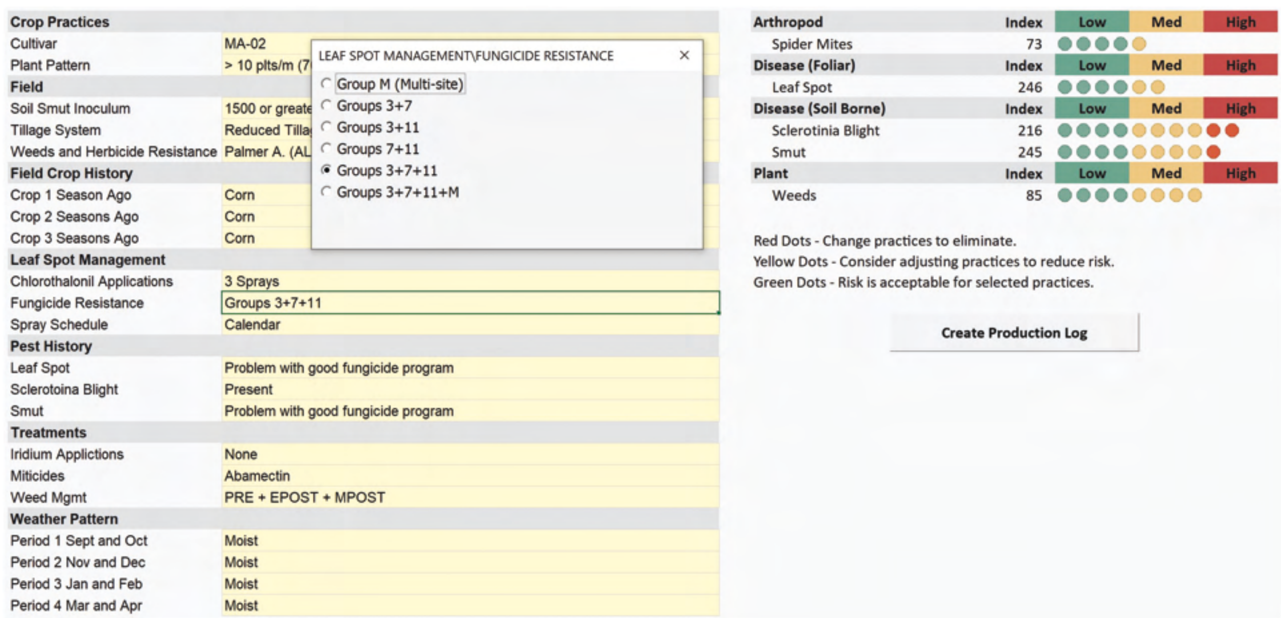


Fig. 20. Drop down menu for fungicide resistance in the Argentina peanut risk tool.

Future Goals for Peanut Risk Tools

The risk tools described for peanut in this article serve as a starting point and are designed for modification as well as expansion to other peanut production areas. In the process of developing these tools several limitations have been identified due to dynamic nature of risk components. First, it is possible that modifications to create tools or portions of tools do not reflect the current knowledge of peanut production systems. Of course, the current versions are not complete in the sense that empirical data sets are a foundation for all of the point designations within and across pest disciplines and individual pests. A considerable amount of the information used in these tools reflects information provided by practitioners that are not verified by experimental data. However, it is important that risk tools created represent the current knowledge base for peanut production and pest management. When tools are modified there also needs to be a reference file that is considered 'official' so that the risk tool is consistent in format and content. With that said, modifications that represent other production areas are a recommended and are a key reason why the initial risk tool was created in Microsoft Excel, especially given the ubiquitous nature of this platform.

A second limitation to the current platform is that it is designed primarily as a planning tool with limited options once the cropping cycle begins. Integrating the tool with other outreach platforms or

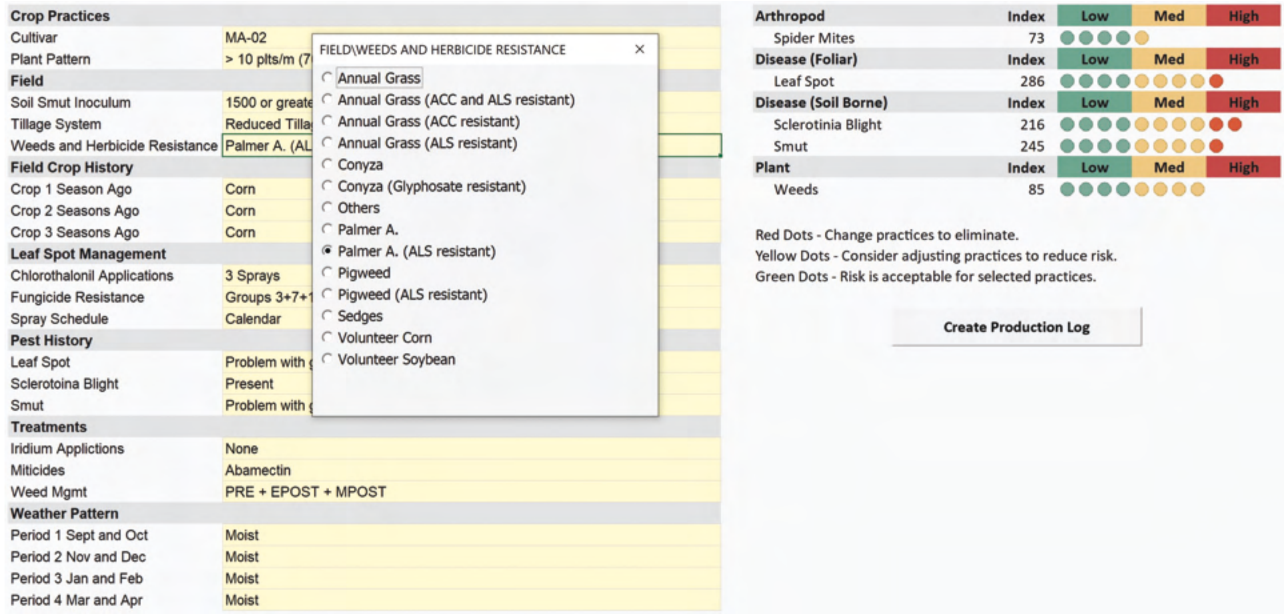


Fig. 21. Drop down menu for weeds based on herbicides resistance in the Argentina peanut risk tool.

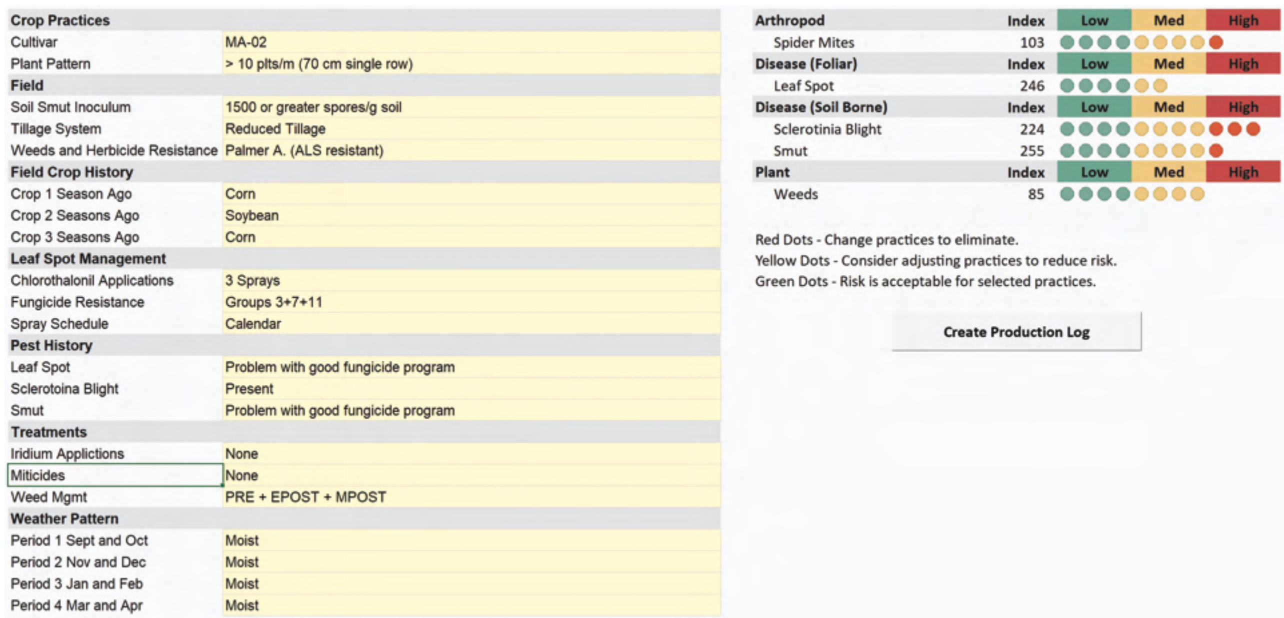


Fig. 22. Risk of two-spotted spider mite infestation when three applications of chlorothalonil are made to peanut in the Argentina peanut risk tool.

applications on smartphones would create a time sensitive approach that would be an important advance. If used appropriately, the current risk tool platform decreases the likelihood that practitioners will begin the cropping cycle with elevated risk. The risk tool also serves as a historical record of a field or group of fields by using the production log feature. In this sense the risk tool is future looking. However, greater flexibility in the risk tool for decision-making during the cropping cycle is needed.

A third limitation to these risk tools is the economic component. While this element serves the user by allowing observations of changes in risk linked to production and pest management costs, moving this component of the risk tool toward a true financial comparison using empirical and observation data based on net returns rather than a simple cost of pest management would be an improvement. Efforts are currently underway in both Ghana and NC to address this limitation by collecting survey data from farmers using categories listed in the risk tool along with weather data, reported yield for that particular cropping cycle, and yield estimates over a longer period of time.

As with all models and tools, validation is needed with these risk tools. As these risk tools are put into practice, adjustments in distribution of points within categories in context of points in other categories need refinement. None-the-less, these risk tools provide a source of greater information exchange on the complicated nature of pest management in peanut for five countries across four continents.

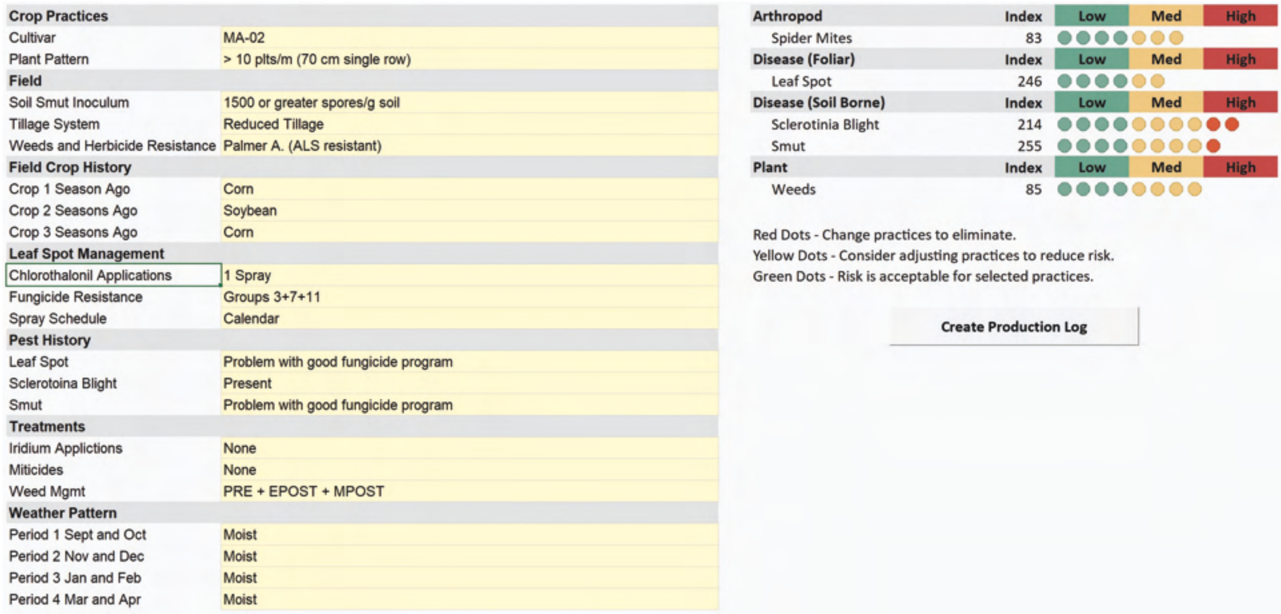


Fig. 23. Risk of two-spotted spider mite infestation when one application of chlorothalonil is made to peanut in the Argentina peanut risk tool.

Fig. 24. Risk of two-spotted spider mite infestation when three applications of chlorothalonil are made and abamectin is applied in the Argentina peanut risk tool.

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Author Contributions

Conceptualization, D.L.J. and G.S.B; methodology, D.L.J. and G.S.B.; investigation, D.L.J., G.S.B., B.B.S., R.B., J.N., M.A., R.O., M.B.M., S.A., R.A., W.M., J.C., S.M., J.A.B., J.H.M., K.S.J., P.J., T.P.P., H.G., P.H., N.M., and G.M.; resources, D.L.J.; data curation, D.L.J. and G.S.B.; original draft preparation, D.L.J.; review and editing, D.L.J., G.S.B., R.B., J.N., M.A., R.O., M.B.M., S.A., R.A., W.M., J.C., S.M., J.A.P., J.H.M., K.S.J., P.J., T.P.P., H.G., P.H., N.M., G.M., D.H., and J.R.; project administration, D.L.J.; funding acquisition, D.L.J. All authors have read and agreed to the published version of the manuscript.

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