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Farmers' Production Practices, Incidence and Management of Pests and Diseases, Extension Services, and Factors Limiting Cotton Production and Quality in South Africa

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ABSTRACT

Cotton is one of the essential cash crops; however, several factors, such as low yields and pest and disease infestations, affect the production. In South Africa, cotton production has increased among small-scale farmers since the late 1990s. Although the crop is not new to South African farmers, no recent information reflects the current status of cotton production practices. A study evaluated farmers' production practices, the incidence and management of pests and diseases, extension services, and factors limiting cotton production and quality in South Africa. One hundred and forty farmers, mainly smallholder farmers, were interviewed during the 2017/18 growing season. Most farmers planted genetically modified (GM) cotton on less than 5 ha of cotton, with 96% planting under dryland. Most farmers neither practised conservation agriculture (95%) nor conducted soil analyses (87%). A mean cottonseed yield of 700 kg ha^{-1} was reported on dryland cotton, and 5 000 kg ha^{-1} was obtained from irrigated cotton. Most of the farmers (99%) harvested their cotton by handpicking. Farmers' pest knowledge was higher than their knowledge of different diseases. Most participants were unaware of nematodes (88%) or disease-resistant cultivars (74%), while 91% were aware of insect-resistant cultivars. Extension officers only mentored and supported many respondents (82%). Most farmers (93%) relied on pesticides to control cotton pests, and the rest (7%) used biological control. Climatic conditions (98%), labour costs (88%), and insect infestations (42%) were identified as the main constraints in cotton production. Although this study had a limited number of surveyed farmers, it gives some insight into their knowledge and challenges.

Keywords: Cotton, Insect Pests, Diseases, Integrated Pest Management, Farmers' Knowledge.

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1. INTRODUCTION

Cotton (*Gossypium hirsutum* L.) is an important cash crop globally (Boyer *et al*., 2017; Tigga *et al*., 2017) and particularly in the Southern African Development Community countries (Gwarazimba, 2009). Cotton is grown in 75 countries worldwide (World Trade Organisation, 2019), accounting for about 80% of natural fibre production (Townsend, 2020). However, South Africa's production is far less than the domestic demand for cotton (Department of Agriculture, Forests and Fisheries, 2011). Cotton is susceptible to a wide range of pests that significantly impact the yield and quality of the fibre (Manjunath, 2004; Karavina *et al*., 2012). The damage caused by these pests is most severe on cotton grown in developing countries. Efficient integrated pest management has long been proposed as essential for efficient cotton production (Fitt *et al*., 2009). However, the concept requires interventions based on a thorough knowledge of the crop, the pests, and the environment (Prudent *et al*., 2007; Tibugari *et al*., 2012). Although pests and diseases in cotton are not new to South African cotton farmers, no recent information reflects farmers' current knowledge of pests and diseases.

Furthermore, the cotton yields among dryland farmers in South Africa continue to be low and individual farmers employ different production practices to improve the yields. Attempts to improve cotton production require a detailed understanding of the farmers' knowledge and needs (Norton & Mumford, 1993; Sinzogan *et al*., 2004). Hence, a survey was conducted to provide more information on cotton farmers' knowledge and perceptions about cotton production in three cotton-producing regions of South Africa. This survey also aimed to give relevant information on the farmers' agronomic activities, the status of the pests and diseases, and their management. The overall objective of this study was to explore farmers' knowledge of cotton pests and cotton production practices in South Africa. This information could assist in identifying research gaps and developing future programmes to enhance cotton production.

2. MATERIALS AND METHODS

2.1. Study Area

The survey study was conducted in three cotton-producing provinces of South Africa. Five regions were surveyed as the representative area. The regions were Nokaneng-Mpumalanga (25°5'S; 28°38'E), Tonga-Mpumalanga (25°40′S; 31°52′E), Makhathini-KwaZulu-Natal

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(27°42'S; 32°10'E), Groblersdal-Limpopo (25°09′S; 29°23′E) and Marble Hall-Limpopo (24°58′S; 29°18′E).

2.2. Survey Sampling

A questionnaire was sent to 200 randomly selected farmers to gather information on cotton pests and production practices. The number of farmers interviewed in each area depended on the participation and availability of farmers. The survey was conducted on the region's recognised cotton farmers. The survey involved both electronic and manual surveys of mainly smallholder cotton producers. Of the 200 farmers, 140 (70%) completed and returned the questionnaires.

2.3. Data collection

Information for this study was gathered from a farmers' survey conducted between April and August 2017. The questionnaire was designed to obtain information on farmers' production practices, the incidence and management of pests and diseases, extension services, and factors limiting cotton production and quality (Table 1). With the assistance of Cotton South Africa, the questionnaires were pre-tested with some farmers in the surveyed areas before the study was conducted to ensure that farmers had no problem understanding them. Where required, translation was done into the language of the farmers, and then their answers were translated back into English. Questionnaires were distributed to the selected farmers. The questionnaire required approximately 10 minutes to complete. There was no financial incentive for responding or any known risk for the participating farmers. All information supplied by the participants was regarded as confidential, and no individual farmer's responses were shared with any other party or person.

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TABLE 1: Summary of the Questions Included in the Questionnaire

Data group	Description
Farm details	Area where the farm is situated; Number of hectares planted under irrigation and dryland; Typical environmental conditions and soil type of the field/region (average rainfall, temperature, soil type)
Production practices	Names of varieties usually planted; Preferred variety; Conservation agriculture practice; Conduct soil analysis; Harvest methods (handpick, machine); Average yield per hectare for the past five seasons; Handling of left-over cottonseed
Incidence and management of pests and diseases	Resistance of the variety to diseases and insects; Awareness, incidence, and economic importance of diseases and pests; Management strategies to protect the cotton from diseases and pests
Extension service and factors limiting the yield	Source of advice on varieties to plant; Field visits by researchers and frequency; Supplier of cottonseed; Limiting factors for higher yields (irrigation, fertiliser, labour, climate, disease, insects, weeds); Weed types and constraints in controlling weeds; Cotton production research requirements

2.4. Data analysis

Survey data from the questionnaires were summarised and conveyed using descriptive statistics (means and percentages) based on the total number of affirmative responses compared to the total number of responses received. For each question, the percentage of farmers who gave similar responses was calculated for each site. The percentages were calculated by dividing the number of responses to that question by the total number of responses and multiplying by 100. Data collected were combined for analysis and presented in percentages in the form of tables.

3. RESULTS AND DISCUSSION

3.1. Climatic Condition and Soil Type of Selected Study Areas

The survey was conducted on cotton farmers from some of the major cotton-producing regions in South Africa. The respondents were mainly from KwaZulu-Natal (70%) followed by Mpumalanga (28%). Farms used for the study have mainly loam (22%) and sandy (56%) soil

(Table 2). The overall mean rainfall reported by the respondents during the survey was 450 mm. KwaZulu-Natal reported 498 mm, while Limpopo and Mpumalanga reported 500 mm and 350 mm, respectively. Rain is crucial after planting or during emergence, and rainfall of 15 to 20 mm after planting promotes a good stand of cotton (Dippenaar, 2015). The mean summer temperature was 26.7°C, which is a suitable temperature for cotton production. As cotton is a tropical crop, it prefers summer temperatures of 25°C or higher (Coleman, 2019) and is favoured by soil temperatures above 18°C during germination (Boman & Lemon, 2005). Krzyzanowski & Delouche (2011) reported that the optimal temperature for cotton germination is 28ºC to 30ºC and that the germination rate decreases as temperatures go above 33ºC or below 20ºC. Cotton should also not be planted before the top 30 mm of the soil has maintained a temperature of 16 to 18°C or higher for approximately ten days (Dippenaar, 2015). However, Dippenaar (2015) also noted that in Limpopo, Mpumalanga, and KwaZulu-Natal, the soil temperature is not a limiting factor for the planting date for cotton.

TABLE 2: Distribution and Details of Each Area Based on the Sampled Participants

Variables	**n = 140 (%)**
Area where the farm is situated	
KwaZulu-Natal	70%
Limpopo	2%
Mpumalanga	28%
Soil type	
Clay	16%
Loam	22%
Loam clay	3%
Sandy	56%
Sandy loam	3%
Mean rainfall	
KwaZulu-Natal	498 mm
Limpopo	500 mm
Mpumalanga	350 mm
Mean temperature	
KwaZulu-Natal	29°C

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Limpopo	25°C
Mpumalanga	26°C

3.2. Farm Size and Irrigation Source

On average, cotton was grown on six ha per household, but this varied significantly across provinces, ranging from one ha in Mpumalanga and KwaZulu-Natal to 200 ha in Limpopo (Table 3). The farm with 200 ha of cultivated cotton belonged to a commercial farmer. Most (62%) of the farms included in the survey had less than five hectares of land under cotton cultivation. Cotton South Africa (2017) reported that in South Africa during the 2016/17 season, 33 628 hectares were planted (19 273 ha irrigated and 14 355 ha dryland). 134 farmers (96%) planted dryland cotton, while only 12% had irrigated cotton fields. Most smallholder farmers in South Africa cultivate cotton under dryland conditions. The difference between the two farming systems is that the cottonseed yields are much higher in irrigated fields than in dryland fields.

TABLE 3: Distribution and Details of Each Area Based on the Sampled Participants

Water source	Hectares	Number of farmers	% of Farmers
Dryland	1 > 2	29	21%
	2 > 3	26	19%
	3 > 5	31	22%
	5 > 10	36	26%
	> 10	12	8%
Irrigated	1 > 5	12	9%
	5 > 20	3	2%
	20 > 100	2	1%
	100 > 200	1	1%

3.3. Production Practices

The primary production practices of the farmers are provided in Table 4. Cultivar PM 3225 B2RF from Monsanto was the variety planted by most participants (89%). This cultivar has the BGII and RR Flex genes, giving it resistance to bollworms and the herbicide glyphosate. It also has hairy leaves, giving it tolerance to jassids but making it unsuitable for mechanical picking.

All the farmers planted GM cotton because no seed is commercially available for non-GM cotton cultivars in South Africa (James, 2014; United States Department of Agriculture, 2017). GM cotton was introduced in South Africa in 1997 as the first GM crop grown by both commercial and smallholder farmers (Thomson, 2016). Today, South Africa is one of the largest producers of GM crops globally. It is by far the largest in Africa (Masinjila, 2018), with most smallholder farmers adopting GM cultivars. Most farmers indicated that the advantages of planting GM cotton were reduced production costs, reduced insecticide use, and higher yields. Gouse, Kirsten and Jenkins (2003) noted yield increases for large-scale irrigated farmers (18.5%), large-scale dryland farmers (13.3%), and small-scale dryland farmers (45.8%) that adopted GM cotton.

Most of the respondents (95%) did not practise conservation agriculture because they cited unfamiliarity with the concept. Thierfelder *et al*. (2016) stated that conservation agriculture is the solution to water-conserving and sustainable cropping systems, which may be affected by unpredictable climatic conditions and frequent droughts in southern Africa. However, available estimates of its adoption currently suggest that smallholder farmers have not adopted it widely (Brown, Nuberg & Llewellyn, 2017). Most farmers (87%) did not conduct soil analysis before planting their fields. This problem was linked to their financial constraints and a lack of knowledge. Soil analysis is crucial to optimal fertilisation, increasing yields, and lowering the costs of cotton farming (Harper, 2011).

Of the respondents surveyed, 99% harvested their cotton by handpicking. Handpicking is more expensive than machine picking in South Africa. In contrast, Chaudhry (2008) reported that handpicking cotton in mainland China was cheaper than machine picking in Brazil. Although manual cotton harvesting is labour-intensive (Sandhar, 1999), major cotton-producing countries such as Egypt have not considered moving to machine picking because the handpicking of cotton guarantees high quality and puts less stress on the fibres. Farmers (1%) that harvested cotton mechanically used a picker or a stripper. The picker harvests cotton without causing damage to unopened bolls (Deshmukh & Mohanty, 2016; Certi-Pik, 2017) and is generally used only for a yield higher than 5 000 kg ha^{-1} (Coleman, 2019). A stripper device pulls off the entire boll, damaging the stalk, and it is usually used when the yield is lower than 5 000 kg ha^{-1} (Coleman, 2019). A mean cottonseed yield of 700 kg ha^{-1}, with individual fields ranging between 120 kg ha^{-1} and 1 800 kg ha^{-1}, was reported by dryland farmers, while a mean yield of 5 000 kg ha^{-1} was obtained from irrigated cotton. In 2017, the mean cotton yields in South Africa were 4 595 kg ha^{-1} and 910 kg ha^{-1} for irrigated and dryland production, respectively (Cotton South Africa, 2017). Global cotton yields are near the 10-year average of 770 kg ha^{-1} (Cotton South Africa, 2018), a cotton production yield that is usually non-profitable. South Africa's break-even point for high-quality dryland cotton is 1 500 kg ha^{-1} and 3 780 kg ha^{-1} for average-quality irrigated cotton (Coleman, 2019). Many farmers (86%) bought seeds for planting, while 14% used seeds from the previous season.

TABLE 4: Summary of the Production Practices By Cotton Farmers

Variables	**Total respondents**	
	Number	**%**
Cotton varieties usually planted.		
18 + 12B RF	13	9%
Candia + 1541+ DP1	1	1%
DP1240B2RF	1	1%
PM 3225 B2RF	123	89%
Total	138	100%
GM status of the favourite varieties		
GM	93	66%
Non-GM	47	34%
Total	140	100%
Conservation agriculture practice		
No	131	95%
Yes	7	5%
Total	138	100%
Conduct soil analysis		
No	120	87%
Yes	18	13%
Total	138	100%

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Harvesting method		
Handpicking	137	99%
Machine	2	1%
Total	139	100%
Mean yield per hectare (seed cotton)		
Irrigation	5 000 kg ha^{-1}	
Dryland	700 kg ha^{-1}	
Planting of seed bought from the previous year		
No	118	86%
Yes	20	14%
Total	138	100%

3.4. Incidence and Management of Pests and Diseases

The incidence and management of pests and diseases are presented in Table 5. The study found that farmers' knowledge of pests was slightly better than their knowledge of various diseases that attacked their crops. Li *et al*. (2010) reported a similar trend in China, where the early detection and treatment of cotton diseases are uncommon. They recommended guidance from experts and a diagnostic system to help cotton farmers. Those who were aware of diseases on cotton knew about *Verticillium* wilt (10%), *Fusarium* wilt (8%), boll rots (23%), virus diseases (5%), seedling diseases (9%), and bacterial blight (12%). Those farmers aware of *Verticillium* wilt further reported how difficult it was to control this disease and its contribution to yield loss. These observations correspond with studies that have identified *Verticillium* wilt as one of the key reasons for low cotton yields among smallholder farmers (Mapope, 2001; Chapepa *et al.*, 2015; Yuan *et al*., 2017). Controlling *Verticillium* wilt is challenging because it can infect a broad host range (Trapero *et al*., 2015), and there are few registered control measures. The Agricultural Research Council-Industrial Crops has developed two cotton cultivars resistant to *Verticillium* wilt; however, their adoption has been limited (unpublished). Cotton bollworms were recognised by 89% of the respondents. Larvae of these species are regarded as major pests of cotton in South Africa (Fourie, Van den Berg & Du Plessis, 2017). Other insect pests mentioned included aphids (84%), cotton stainers (96%), spider mites (91%), leafhoppers (known as jassids locally) (84%), and whiteflies (32%). Most participants (88%) indicated that they were unaware of nematodes on cotton in their fields. Fifty-eight farmers (58%) were aware of insect pests other than the ones listed above.

The farmers' knowledge of pests in cotton production from the sampled area may be related to the high number of these insects in their cotton fields. Also, there is a high potential that these insects cause crop damage and low yield for dryland farmers. Most of the participants indicated that there was a high prevalence of spiders (91%), ants or termites (87%), ladybirds (80%), and parasitic wasps (76%). While 91% of participants knew of insect-resistant cotton varieties, only 26% knew of disease-resistant varieties. Although most respondents reported that they rely on GM varieties to control pests and diseases, their yields will be compromised if some insects resist commonly used pesticides (Kranthi *et al*., 2019). The participants identified bollworms (42%) and leafhoppers (31%) as the main pests that the GM varieties provide resistance against, while the *Verticillium* wilt (26%) was regarded as the main disease that GM varieties provide resistance against. Where possible, host resistance is the most effective, natural, and affordable strategy to control *Verticillium* wilt (Klosterman *et al*., 2009; Tsror, 2011). Most farmers used pesticide sprays to control cotton pests (57%). Due to limited research on the biological control of cotton pests in South Africa, only 7% of the survey farmers used biological control methods. Chemical control of insect pests must be integrated with other control measures to be fully effective (Hillocks, 1995; Gautam *et al*., 2023). Only 9% used fungicide sprays to control cotton diseases, while 44% relied on resistant cultivars, despite only 26% of the farmers being aware of disease-resistant cotton varieties.

Chemical control (31%) was mainly used as a management strategy for the control of both pests and diseases, followed by resistant cultivars (27%) and biological control (2%), such as reliance on natural enemies. Where crop development is adversely affected by diseases, weed infestation, or poor crop management, the effectiveness of chemical control cannot be realised (Hillocks, 1995). Only 1% of the respondents said they received advice from other farmers. This confirms the observation by Midega *et al*. (2012) that mechanisms are required to train and encourage the farmer-to-farmer transfer of appropriate pest management information.

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TABLE 5: Farmers' Perceptions of Cotton Pest and Disease Incidence and Their Management Practices

Variables		**No of farmers**	**% of**
Awareness of diseases	*Verticillium* wilt	No: 123	90%
		Yes: 13	10%
	Fusarium wilt	No: 124	92%
		Yes: 11	8%
	Boll rots	No: 103	77%
		Yes: 31	23%
	Virus diseases	No: 123	95%
		Yes: 7	5%
	Seedling diseases	No: 127	91%
		Yes: 12	9%
	Bacterial blight	No: 120	88%
		Yes: 17	12%
	Other	No: 82	59%
		Yes: 58	41%
Awareness of pests	Bollworms	No: 16	11%
		Yes: 124	89%
	Aphids	No: 22	16%
		Yes: 118	84%
	Cotton Stainers	No: 6	4%
		Yes: 134	96%
	Spider mites	No: 13	9%
		Yes: 127	91%
	Nematodes	No: 120	88%
		Yes: 16	12%
	Leafhoppers	No: 23	16%
		Yes: 117	84%
	Whiteflies	No: 95	68%
		Yes: 45	32%
	Other	No: 82	59%
		Yes: 58	41%
Awareness of beneficial insects	Parasitic wasps	No: 34	24%
		Yes: 106	76%
	Ants/termites	No: 18	13%
		Yes: 122	87%
		No: 28	20%

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	Ladybirds	Yes: 112	80%
	Spider	No: 12	9%
		Yes: 128	91%
Resistance of the variety to diseases	Yes	31	22%
	No	6	4%
	Do not know	102	74%
Resistance of the variety to insects	Yes	126	91%
	No	4	3%
	Do not know	8	6%
Type of resistance	Bollworms	40	42%
	Bollworms and jassids	30	31%
	Cotton stainers	1	1%
	Verticillium wilt and	5	5%
	Verticillium wilt and stainers	2	2%
	Verticillium wilt and jassids	18	19%
Management strategies for diseases	No control	15	11%
	Farming practices	2	1%
	Chemical	13	9%
	Resistance cultivars	61	44%
	Biological control	7	5%
	Others	1	1%
Management strategies for insect pests	Chemical	80	57%
	Resistance cultivars	1	1%
	Biological control	10	7%
Management strategies for insect pests and diseases	Farming practices	1	1%
	Chemical	44	31%
	Resistance cultivars	38	27%
	Biological control	3	2%

3.5. Extension Service and Factors Limiting Yield

Data in Table 6 illustrate the level of farmer support, factors limiting cotton yields, and areas requiring more research. Most respondents (82%) received mentoring and support from the extension officers and seed companies (14%), but only 1% indicated that they had received support from the Agricultural Research Council. Only 23% of the participants had been visited by a cotton researcher. Of those seen by a researcher, 63% were visited at least once in the previous season, while only 20% of the farmers experienced more than one visit. The farmers'

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limited knowledge of pests and diseases may be attributed to little information sharing among farmers and the limited mentoring and support from researchers and extension.

Most farmers (91%) purchased their cottonseed from the seed suppliers. Only a few farmers (8%) used seeds bought in the previous year. Most respondents (98%) identified climatic conditions as the primary constraint, followed by the intensive demand for labour (88%) for efficient cotton production on their farms. Farmers in developing countries are more vulnerable to climate change than farmers in developed countries because their agriculture is mainly rain-fed (Intergovernmental Panel on Climate Change, 2007).

Further increases in global temperature and changes in rainfall patterns will significantly reduce cotton yield in Africa (Diarra *et al*., 2017). Problems with insect infestation affected 42% of the farmers, and only 8% reported a combination of different factors. None of the participants identified diseases as a limiting factor to the cotton yield; however, Chapepa *et al*. (2013) had previously noted that diseases remain a major limiting factor in cotton production. Concerning diseases, the participating farmers' perception may be related to the lack of support from the trained personnel who should provide information on the role of diseases on the yield. The farmers reported difficulties in controlling weeds, especially morning glory (*Ipomoea purpurea*) (33%) and nutsedges (*Cyperus esculentus* and *C. rotundus*) (21%).

However, more than a third (35%) of the respondents reported that they did not experience any weed problems, possibly because they successfully used glyphosate on Roundup Ready cotton varieties to manage weeds. Morning glory is one of the most problematic weeds due to its extended emergence period (Jha *et al*., 2006; Jha & Norsworthy, 2009) and abundant growth capabilities (Sellers *et al*., 2003; Norsworthy *et al*., 2008). Kerr (2016) described nutsedges as the world's most damaging weeds, with two primary species of nutsedge being found in South Africa. Commercial farmers practice effective chemical control methods for these weeds (Reinhardt, 2016; Burke *et al.*, 2008). However, smallholder farmers cannot afford to use effective herbicides. The farmers believed that the problem of low cotton yields could be resolved through research on pest control (45%), weed control (19%), soil analysis (5%), and breeding for new cotton varieties (17%). The handpicking of cotton is more of a labour issue, with some farmers concerned about the high costs involved. Some farmers (14%) recommended mechanical harvesting as an alternative. Conservation agriculture would allow farmers to reduce labour constraints and increase yields compared to conventional methods

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(Grabowski & Haggblade, 2016; Thierfelder *et al*., 2016). Although many farmers cited rainfall and heat as factors most limiting cotton yields, none of the farmers supported research on climate change. This could be because the surveyed farmers are unfamiliar with climate change.

TABLE 6: Summary of the Extension Service Rendered, Factors Limiting Cotton Yields, and the Topics on Which More Research is Required

Questions posed to farmers		**Farmers' response (%) N=140**
Who advises you on what variety to grow?	ARC	1%
	Chemical agents	1%
	Extension officer	82%
	Farmer	1%
	Seed company	14%
	Other	1%
Has a researcher visited your field?	Yes	23%
	No	77%
If yes, what is the number of visits in the past season?	Visits: 0	17%
	Visits: 1	63%
	Visits: 2	20%
Where do you get your cottonseed?	Cooperative	8%
	Gin	1%
	Seed company	91%
Which factors were the most limiting to your cotton yield?	Climate	98%
	Insect	42%
	Labour	88%
	All factors	8%
Identify difficulties in controlling weeds and mention types of weeds involved	Morning glory	33%
	Nutsedge	21%
	Kweek grass (*Cynodon dactylon*)	2%
	No weed problem	35%
	Other	9%

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If you could choose, in which area of cotton production would you like to see research?	Mechanical harvesting	14%
	Pest control	45%
	Weed control	19%
	Soil analysis	5%
	New cultivars	17%

4. CONCLUSION

This study evaluated farmers' production practices and the incidence and management of pests and diseases. The study further sought to report the farmers' views of extension services and factors limiting cotton production and quality in South Africa. Despite the limited sampling area of the survey, the outcomes of this study offer some insight into farmers' knowledge of the pests and practices of cotton. The study may be helpful in the development of integrated pest management practices and identify inefficiencies in production practices in the industry to increase yield, reduce pesticide use, and increase gross margins. These results could assist in the development of effective agricultural extension programmes for farmers engaged in cotton production.

5. RECOMMENDATIONS

Based on the outcomes, the survey recommends 1) the development of novel cotton cultivars to combat diseases, weeds, and the detrimental effects of climate change; 2) technology transfer to enhance farmers' awareness of nematodes and diseases; 3) the development of alternative control methods to reduce the use of agrochemicals; 4) technology transfer to cotton farmers on the application of conservation agriculture; 5) technology transfer to farmers on the value of soil analysis; and 6) frequent visits by researchers to advise and mentor the farmers, and to learn from the farmers. A further survey, including all the cotton-producing areas in South Africa, needs to be undertaken to verify the outcomes of the current study.

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