COWPEA (*Vigna unguiculata* (L.) Walp) SEED QUALITY AND YIELD AS INFLUENCED BY MANIPULATING SOWING DATES FOR THE MANAGEMENT OF SCAB INDUCED BY *Elsinoe phaseoli* Jenkins, AT SAMARU, NORTH-WEST NIGERIA

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DEPARTMENT OF CROP PROTECTION
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DECLARATION

I hereby declare that the work in this dissertation titled "**Cowpea (*Vigna Unguiculata* (L.) Walp) Seed Quality and Yield as Influenced by Manipulating Sowing Dates for the Management of Scab Induced by *Elsinoe Phaseoli* Jenkins, at Samaru, North-West Nigeria**" was carried out by me in the Department of Crop Protection, Ahmadu Bello University, Zaria, under the supervision of Professor Olufunmilola Alabi, Professor P. S. Chindo and Dr S. E. L. Alao. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this work has been presented for another degree or diploma at any other institution.

Temilade Morounkeji FETUGA	____________________	________________
Name of Student	Signature	Date

CERTIFICATION

This dissertation titled **COWPEA (*Vigna unguiculata* (L.) Walp) SEED QUALITY AND YIELD AS INFLUENCED BY MANIPULATING SOWING DATES FOR THE MANAGEMENT OF SCAB INDUCED BY *Elsinoe phaseoli* Jenkins, AT SAMARU, NORTH-WEST NIGERIA** by Temilade Morounkeji FETUGA meets the regulations governing the award of the degree of Master of Science in Crop Protection of the Ahmadu Bello University, Zaria and is approved for its contribution to scientific knowledge and literary presentation.

Chairman, Supervisory Committee Professor Olufunmilola Alabi	____________________ Signature	______________ Date
Member, Supervisory Committee Professor P. S. Chindo	____________________ Signature	______________ Date
Member, Supervisory Committee Dr S. E. L. Alao	____________________ Signature	______________ Date
Head of Department Professor O. O. Banwo	____________________ Signature	______________ Date
Dean, School of Postgraduate Studies Professor S. Z. Abubakar	____________________ Signature	______________ Date

DEDICATION

This work is dedicated to the Almighty God. The One who sits upon the throne of authority of the universe; the Prince of the kings of the earth.

"To whom then will I liken You? Or what likeness will I compare unto You?"

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ABSTRACT

Field experiment was conducted at the Institute for Agricultural Research (IAR) farm at Samaru, North-western Nigeria to investigate effects of sowing dates on incidence and severity of scab on yield and seed quality of cowpea. The varieties, SAMPEA 6, SAMPEA 8, SAMPEA 11, TVx 3236 and Ife brown were planted at three sowing dates, August 9, 19 and 29 in 2016. The design used was Randomized Complete Block Design (RCBD) with three replications. Parameters measured were disease incidence, disease severity and yield. Disease incidence and severity scores were taken at weekly intervals for ten weeks, and data was analysed using SAS statistical software. Cowpea sown on the first sowing date August 9, had the highest scab incidence, 48.89 %, 54.44 %, 36.67 %, 20 % and 13.33 % and severity, 25.11 %, 31.44 %, 18.33 %, 19.56 %, 18.11 % on leaves, stems, peduncles, flower cushions and pod, respectively while plants sown on the third sowing date, Aug 29, had no scab infection. The varieties, SAMPEA 11 and TVx 3236 had low incidence and severity and can be considered to be moderately resistant to scab. The yield of cowpea sown on August 9 was the highest (1,792.60 kg/ha), followed by that sown on Aug 29 (1,422.20 kg/ha) while cowpea sown on Aug 19, had the lowest (1,192.60 kg/ha). However, the yield of Aug 19 and 29, sowing dates were not significantly different from each other ($P \geq 0.05$). The variety, SAMPEA 11 had highest yield (1,691.40 kg/ha) while in this study, TVx 3236 had the lowest (1,296.30 kg/ha); average potential yield of TVx 3236 had been put at 1,200 kg/ha. Path coefficient analysis showed that severity of scab on pod contributed highly to reduction in yield per hectare (18.94 %), followed by scab on flower cushion (16.42 %). Seed quality tests, germination and accelerated ageing were conducted at Legumes Pathology Laboratory, Department of Crop Protection, Ahmadu Bello University, Zaria while electrical conductivity test was at National Agricultural Seeds Council Laboratory, Sheda, Abuja. Seeds harvested from cowpea sown on August 29 sown cowpea had highest germination of 90 % and vigour, 82.07 % which was significantly different ($P \leq 0.05$) from those sown on August 9 with lowest germination of 67.20 % and vigour of 64.47 %. Correlation coefficient analysis showed that scab severity on the different plant parts had negative and highly significant effects on viability and vigour of the seeds. Scab severity had a positive correlation with electrolyte leakage. Negative and significant correlation was observed between electrical conductivity and germination (r = -0.330*). This was similarly observed with accelerated ageing tests (-0.224), though not significant. Path coefficient analyses showed that scab severity had effects on seed quality, causing a reduction of 73 % and 92.5 % on seed viability and vigour respectively. SAMPEA 11 and TVx 3236, despite its low yield which could be attributed to the small seed size, sown by second week of August should form an integral part for the management of scab in cowpea.

TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF PLATES

LIST OF APPENDICES

CHAPTER ONE

1.0 INTRODUCTION

Cowpea *(Vigna unguiculata,* L Walp) is a leguminous crop indigenous to Africa and a dicotyledonous plant belonging to the family Fabaceae (Schippers, 2002). It can be grown as sole crop, but more often planted alongside crops such as sorghum, maize or millet (Agbogidi, 2010a). More than 5.4 million tonnes of cowpeas are produced worldwide, with Africa being the highest producer with nearly 5.3 million tonnes annually (IITA, 2010). Nigeria, as the largest producer and consumer of cowpea, accounts for 61 % of production in Africa and 58 % worldwide, out of which Nigeria produced 5.1 million tonnes under cultivation area of 3.59 million / ha (NAERLS & FDAE, 2013).

Cowpea is one of the oldest crops known to man and an important food legume because of its nutritional value to man and usefulness as fodder to livestock (Agbogidi, 2010b; Davis *et al*., 1991). Its ability to replenish soil nitrogen makes it important in the modern crop farming system in rotation with other crops (Langyintuo *et al*., 2003). Also, its drought tolerance, relatively early maturity and nitrogen fixation characteristics fit very well to the tropical (humid) soils where moisture, erosion and low soil fertility is the major limiting factor in crop production (Hall, 2004). It serves as food security and at the same time can be combined with other recipe (Muoneke *et al*. 2012).

The average yields of cowpea are generally low (Benue State Agricultural and Rural Development Authority (BNARDA, 2009). This can be attributed to many factors amongst which are drought, low soil fertility, parasitic weeds, insect pests, and diseases (Olufajo and Singh, 2002; Niringiye *et al.,* 2005; Fawole *et al*., 2006). The major insect pests of cowpea include: the legume pod borer, *Maruca vitrata* Fabricius; the coreid pod-bugs, *Clavigralla tomentosicollis* Stal; the groundnut aphid, *Aphis craccivora* Koch;

and thrips, *Megalurothrips sjostedti* Trybom and *Sericothrips occipitalis* Hood (Jackai, 1995; Tanzubil, 2000; Malgwi and Onu, 2004). Opareke *et al*. (2000) estimated yield loss in cowpea due to insect pests to be above 80%. Cowpea is also attacked by parasitic flowering plants such as *Striga gesnerioides* which causes important yield losses of between 30-80% (Muleba *et al.*, 1997); the nematode *Meloidogyne* spp causes cowpea root knot (Sikora *et al.*, 2005). The disease induced by fungi and bacteria include cowpea scab, *Elsinoe phaseoli*; cowpea wilt, *Fusarium oxysporium* f. sp. *Lycopersici*; and cowpea bacterial blight, *Xanthomonas vignicola* among others (Emechebe and Lagoke, 2002).

Scab, induced by *Elsinoe phaseoli* is a seed-borne disease that affects all above ground parts of the plant (leaves, petioles, stems, peduncles and pods) at all stages of growth (Emechebe, 1980; Iceduna, 1993; Mbong *et al*., 2010b), with yield losses of up to 80% and even total crop destruction under severe conditions reported in Nigeria (Emechebe, 1980; Mungo *et al*., 1995). Low seed viability and vigour in plants have been attributed to seed-borne fungi (Elias *et al.,* 2004); infected seeds may fail to germinate, or transmit disease to the seedling and to the growing plant (Fakir *et al.,* 2002). Nabakka (1997) reported germination reduction of up to 59.3% on cowpea seeds which was as a result of seed-borne fungi infection; Mew *et al.* (1994) reported that the quality of seeds account for at least 5–20% increase in productivity.

1.1 Justification of the Study

Cowpea is an important grain legume in Nigeria (FAO, 2012) because it serves as cheap and rich source of protein, minerals, and vitamins in diets (Davis *et al*., 1991) and the fodder is also useful as feed to livestock (Agbogidi, 2010b). The potential yield has been estimated to be between 1,500 - 2,000 kg/ha, though average obtainable yield ranges between 200 – 400 kg/ha (Wakili, 2013). This is due to prevalence of abiotic and biotic factors which affect both yield and quality of the crop.

Scab, induced by *Elsinoe phaseoli* accounts for between 30% to 100% yield loss of the country's total cowpea crop production (Mungo, 1996 and Mbong *et al*., 2010b) through reduction in yield components such as number of seeds per pod and number of pods per plant (Tumwegamire *et al.,* 1998). The disease has a puckering effect on leaf lamina, reducing the photosynthetic surface area of affected leaves (Tumwegamire *et al.,* 1998). The most destructive phase is on the flowering axis causing flower and pod abortion or even completely preventing flower formation (Emechebe, 1980).

A most widely used method employed in the management of scab is application of mancozeb (Dithane M-45) (Iceduna, 1993). Excessive and indiscriminate use of fungicide has led to problems of resistance build up, fungicide residues, and environmental hazards. This has necessitated the search for alternative control method (Narayanasamy, 2008; Gurjar *et al*., 2012). One of such method is manipulation of sowing date which determines the ability of crops to escape infection by pathogens (Cook and Baker, 1996). Cowpeas have been reported to escape infection by *Cercospora* leaf spot (Akande *et al.,* 2012) due to manipulation of the sowing dates.

Seed quality is a crucial determining factor of yield and quality of crop production; it has a significant effect on seed germination and seedling vigour (Wimalasekera, 2015). Seed-borne pathogenic fungi can greatly affect seed quality and cause diseases that impact seedling production and yield (El-Gali, 2015). The effect of seed-borne pathogens such as *Macrophomina phaseolina* on germination and seed vigour has been reported by Nabakka (1997) to cause 59.3 % germination reduction in cowpea; however, the effect of *Elsinoe phaseoli* on seed quality of cowpea has not been investigated.

The aim of this study is to relate the influence of sowing date on scab incidence and severity and provide farmers information on the possible date to sow in order to reduce scab infection and obtain high yield and good quality seed.

1.2 Objective of the Study

The objectives of this study are to:

I. Determine the effect of sowing dates on scab and yield of selected cowpea varieties.

II. Determine the effect of sowing dates and scab on seed quality of cowpea.

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CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Origin, Distribution and Taxonomy of Cowpea

Cowpea (*Vigna unguiculata* (L.) Walp) is a warm season, annual legume of the family Fabaceae, and order Leguminosae; a diploid plant containing 22 chromosomes (2n=2x=22) (Timko and Singh, 2008) and its nuclear genome size is estimated to cover 620 million base pairs (Mbp) (Timko *et al*., 2008). It is one of the most prehistoric human food sources. In Nigeria, it is referred to as beans, while the local names are "ewa" (Yoruba), "wake" (Hausa) and "ikedi" (Igbo) (Singh and Ajeigbe, 1998). Inadequate archaeological evidence has resulted in conflicting views supporting Africa, Asia and South America as origin (Department of Agriculture, Forestry and Fisheries, South Africa, 2011).

Cowpea is extensively cultivated in Africa, Asia, Australia, Brazil, the Caribbean, India and the United States of America (U.S.A) (FAO, 2008). The key producing areas in Nigeria are within the Guinea and Sudan savannas (Mungo, 1996). However, some appreciable quantities are grown in the rain forest belts, particularly in the South West. The major producing states in Nigeria include Kaduna, Katsina, Zamfara, Bauchi, Sokoto, Kebbi, Plateau, Borno, Yobe, Jigawa, Niger, Benue, Nasarawa and Kano where most cowpeas are traditionally grown as intercrops with cereals such as millet, maize and sorghum (Chemeda, 1997).

2.1.1 Uses and nutritional value

Cowpea grain contains 26.6 % protein; 4 % lipid; 56.2 % carbohydrates; 8.6 % moisture; 3.8 % ash; 1.4 % crude fibre; 1.5 % gross energy; and 54.9 % nitrogen free extract (Owolabi *et al*., 2012). Folic acid and vitamin B contents have been found in higher quantity in cowpea compared to other plants and these are essential during pregnancy to prevent birth defect in the brain and spine (Timko and Singh, 2008). As an important source of protein, minerals, and vitamins in daily diets, it positively impacts on the health of human. Hence, the consumption of even a small amount of cowpea ensures the nutritional balance of diet and enhances the protein quality by the synergistic effect of high protein and high lysine (Davis *et al.*, 1991). It also contains bioactive antioxidants such as Vitamin C, carotenoids and phenolic compounds which prevent development of diseases such as atherosclerosis and cancer (Omae, 2011).

Cowpea can be boiled and eaten alone or with "*Gari*" (a cassava product) or boiled together with rice; the boiled grains could also be served with fried ripe plantain or yam (Quaye *et al.*, 2009; Bosah, 2013). It is also used in preparation of weaning foods (Sefa-Dedeh, 2005). Furthermore, cowpea forage (stems, leaves, and vines) serve as animal feed and are often stored for use during the dry season. Its ability to replenish soil nitrogen gives it a key position in the modern crop farming system in rotation with other crops, with the view for long term sustainable agriculture development prospect and can also be used as cover crop (Langyintuo *et al.*, 2003). According to Hall (2004), its drought tolerance, relatively early maturity and nitrogen fixation characteristics fit very well to the tropical soils where moisture, erosion and low soil fertility is the major limiting factor in crop production.

2.1.2 Morphology and growth pattern of cowpea

Cowpea [*Vigna unguiculata* (L) Walp.] exhibit different morphological forms; some are prostrate, erect or semi-erect. It has a deep taproot system with many lateral branches in the surface soil and many globular nodules. The root nodules are smooth and spherical, about 5mm in diameter, numerous on the main taproot and its branches but sparse on the smaller roots (Chaturvedi *et al*., 2011). Growth forms of the plant vary and may be erect, trailing, climbing or bushy, usually indeterminate under favourable conditions.

Leaves are alternate and trifoliate, usually dark green. Stems are straight, smooth or slightly hairy, sometimes tinged with purple (Aveling, 1999).

In cultivated forms, the flowers open at the end of the night and close in late morning, with the dehiscence of the anthers taking place several hours before the flower opens. After blooming (opening once) they wilt and collapse. Seeds of cultivated cowpea types weigh between 80 mg and 320 mg and range in shape from round to kidney-shaped. The seed coat varies in texture (such as smooth, rough, or wrinkled), colour (white, cream, green, buff, red, Brown, black), and uniformity (solid, speckled, or patterned) (Timko and Singh, 2008).

2.1.3 Climatic requirement

Cowpea grows primarily under humid conditions. It is tolerant to heat and drought conditions. The crop is sensitive to frost. It germinates rapidly at temperatures above 18 °C; colder temperatures slow germination (Davis *et al.*, 1991). Cowpea can be grown under rain-fed conditions as well as by using irrigation or residual moisture along river or lake flood plains during the dry season, with the minimum and maximum temperatures between 28 and 30 °C (night and day) during the growing season (Dugje *et al.,* 2009). Most of the crop grown in agro-ecological zones requires an annual rainfall ranging between 500 and 1200 mm. However, with the development of extra-early and early maturing cowpea varieties, the crop can thrive in the regions with an annual rainfall less than 500 mm. The crop requires well drained sandy loams where pH is in the range of 5.5 to 6.5 (Davis *et al.*, 1991), however, it is tolerant of drought and well adapted to a wide range of soils, including sandy and even poor soils (Davis *et al.*, 1991).

2.1.4 Cowpea production

In Nigeria, cowpea is majorly produced in the north in the savannah belt. Its yield in the south is affected by some environmental factors including rainfall hence it is seasonal (Agbogidi and Egho, 2012). Due to the increase in demand for the crop, arising from the growing population in the country, Nigeria remains the largest producer and consumer of cowpea both in West Africa and in the World (FAO, 2010 and IITA, 2011). In the country, the greatest production of cowpea comes from the Northern region. The north produces about 2.5 million tonnes which represents over 60% of the total production (FAO, 2012). Sole cropping system with the use of improved technologies can yield 1,500 - 2,000 kg/ha of cowpea. However, 200 - 250 kg/ha yield is obtained by small scale farmers who are the domestic producers in the country (Wakili, 2013).

2.1.5 Production constraints

Cowpea is a resilient crop that can produce reasonably well under conditions that may render other crops unproductive, but production is still constrained by several biotic and abiotic factors (Hall *et al*., 1997). The biotic factors that cause yield reduction include insect pests, parasitic flowering plants, as well as viral, fungal and bacterial diseases (Emechebe and Lagoke, 2002) while the abiotic factors include poor soil fertility, drought, heat, acidity and stress due to intercropping with cereals (Singh and Tarawali, 1997; Singh and Ajeigbe, 2002).

2.2 *Elsinoe phaseoli*

The fungus *Elsinoe phaseoli* (Jenkins) is the causative organism for scab belonging to the order Myriangiales in Ascomycetes which are parasitic to plants (Fan *et al*., 2017). The organism was first reported in Cuba in 1930 by Jenkins on lima beans (*Phaseolus lunatus*). Similarly, the organism has also been reported in various countries of the world; United States of America (Sitterly and Epps, 1958); Brazil on *P. vulgaris* (Lasca, 1978); Kenya in 1976 on beans (Mutitu, 1979); Nigeria on beans, *Vigna Unguiculata* (Emechebe, 1980); South Africa on *P. vulgaris* (Philips, 1994); Uganda (Iceduna *et al*., 1994; Nakawuka and Adipala, 1997 and Edema *et al*., 1997). Schwartz (1991) reported that the organism is common on *Phaseolus* beans in East Africa.

Sphaceloma sp has been reported as the anamorph (imperfect) stage of *E. phaseoli* because it lacks the sexual reproduction (Afutu *et al*., 2016) and has been reported to cause scab of cowpea (Emechebe, 1980). It was described by Barnet and Hunter (1987) as having disc shape or cushion shaped acervuli, waxy with simple conidiophores which are closely grouped or compacted arising from stroma-like base; conidia hyaline; one celled ovoid or oblong and similar to *Gloeosporium* and *Colletotrichum*. Ayodele and Kumar (2014) on the other hand described it as having hyaline mycelium, scanty and submerged; hyaline to pale coloured conidia which are produced in pycnidia; hyaline ascopores borne on the asci and 3 septate.

The organism *Elsinoe* spp. had been reported to cause scab diseases in other plants such as citrus scab, *Elsinoe fawcetti* (Bitancourt and Jenkins); grape anthracnose, *E. ampelina* (Shear); raspberry anthracnose, *E. veneta* (Burkholder); avocado scab, *E. persea* (Jenkins); mango scab, *E. mangiferae* (Bitancourt and Jenkins).

2.2.1 Scab

Scab affects all the above ground parts of the plant, namely leaves, petioles, stems, peduncles and pods (Emechebe, 1980; Iceduna, 1993; Mbong *et aI*., 2010b). It is one of the most destructive diseases of cowpea in Nigeria and could account for more than 30 % - 80% of the country's total cowpea crop production losses (Mungo et al., 1995; Mbong *et al.,* 2010b). Total crop destruction under disease epiphytotic conditions have been reported in Nigeria (Emechebe, 1980; Mungo *et al*., 1995).

The appearance of small greyish lesions are visible on the infected leaves giving rise to shot holes which may be confused with insect damage (Iceduna, 1993) which under severe conditions lead to leaf distortions and ragged appearance (Singh *et al*., 1997), it has a puckering effect on the leaf lamina which reduce the photosynthetic surface area of the leaves (Tumwegamire *et al.,* 1998). Infected stems show oval to elongated silver grey lesions surrounded by red or brown elliptical rings with lesions coalescing and forming distortions under severe infections. On the other hand, sunken spots with grey centres surrounded by Brown borders appear on infected pods, leading to malformation and, with heavily scabbed young pods aborting or remaining attached to the plant as mummified black masses (Iceduna, 1993; Singh *et al*., 1997).

Primary inocula for infection is provided by an infected seed or plant material (Lin and Rios 1985; Emechebe 1988), while subsequent dispersal of secondary conidial inoculum may be by rain splash, run-off and wind-driven moisture (Emechebe and Shoyinka 1985). However, Mungo (1996) reported cowpea debris as a source of primary inoculum under natural conditions. Conditions conducive for disease development have been described as moderate temperatures of about 23-28 °C, with 3 or more consecutive days of wet weather resulting in high relative humidity (Emechebe and Shoyinka, 1985; Emechebe & Florini, 1997); however, Iceduna (1993) observed more disease during dry conditions in Uganda.

The management strategies of scab include use of resistant varieties (Afutu *et al.,* 2016); application of mancozeb (Dugje *et al.,* 2009); sanitation and crop rotation (Mungo *et al.,* 1995); use of cow dung (Alabi and Emenchebe, 2006) and sowing date manipulation (Mbong *et al.,* 2010a) among others.

2.3 Effect of Sowing Date on Incidence and Severity of Scab

Agrios (2005) defines incidence of disease as the number or proportion of plant units that are diseased, whereas Madigan & Martinko (2006) stated that incidence is the number of plants diseased (when the leaves, stems and/or fruit show any symptoms) in a population. Severity of a disease is described as the proportion of the plant tissue that is affected (Agrios, 2005).

Sowing date is one of the factors that determine the ability of the crop to escape or avoid infection by pathogens (Cook and Baker, 1996) and may influence infection. Mungo (1996) and Mbong *et al*. (2010a) reported higher disease incidences of scab infection on the early sown cowpea than the late sown; this was ascribed to changes in the microclimate of the environment, within the plant community, which might have favoured early disease development. However, Gurama *et al*., (1998) reported that scab severity was lower on early sown cowpea than on late sown crops. Shailbala and Pundhir (2006) in their study on late blight of potato reported that disease severity was significantly low when planting time was delayed. Subedi *et al*., (2007) in their three year study conducted in Ottawa, Canada reported that late planting of wheat (Mid-May to July) increased scab incidence and severity. The incidence and severity of *Choanephora* pod rot and *Cercospora* leaf spot were observed on early sown and near absent on late sown cowpea; this occurrence was attributed to the amount of rainfall received by cowpea during production which play a more critical role in determining yield and disease incidence (Akande *et al.,* 2012). This confirms report by Edema *et al*. (1997), that scab is more severe under wet conditions and consequent high relative humidity because the conidia are supposedly dispersed by rain splash and wind-driven moisture. They also reported that scab is favoured by high plant populations, which are conducive for rain splash dispersal and high relative humidity.

Environment has been reported to play a major role on growth, survival and dissemination *Fusarium graminearum* which causes scab of wheat accounting for high disease incidence and severity (Gilbert and Tekauz, 2000). This was corroborated by Brennan *et al.* (2005) who observed that the incidence of *Fusarium* head blight (wheat scab) increased under wet and hot condition and that planting date can influence the incidence of disease. It has been reported that *Alternaria* blight of mustard can be avoided to a large extent by adjusting sowing date therefore sowing date is an important factor in incidence and severity of crop diseases (Ayub, 2001). The manipulation of planting dates has been observed to reduce or delay the development of anthracnose disease of sorghum induced by *Colletotrichum graminicola* (Gwary *et al*., 2005; Rekha and Singh, 2015).

2.3.1 Effects of sowing date and Scab infection on yield of cowpea

Grain yields have been reported to be reduced through the deleterious effects of scab on yield components like number of pods, and seeds per pod (Iceduna, 1993). Mbong *et al*. (2010a) reported that the effects of sowing date on the yields of cowpea varieties infected with scab showed that early sown cowpea had lower yields than late sown; grain yield of early sown cowpea were lower in quantity and of poor quality than those of late sown crops, which were higher in quantity and of good quality. Mbong *et al*. (2010b) report on yield result from all the three seasons of their study on three cowpea varieties indicated that early sown cowpea had a lower yield for TVx 3236 and IT93K452-1 than late sown crops; while the reverse was for SAMPEA 6, the third variety and this was in agreement with earlier report for this variety by Gurama *et al*. (1998). In general, the study established that it is better to delay the sowing of moderately resistant cowpea varieties such as TVx 3236 and IT93K452-1 to minimize scab infection which also could affect the pod and seed yields as demonstrated from the higher infections and lower corresponding yields from the early plantings. Asio *et al*. (2005) reported low yield of cowpea planted in the early season in Uganda. Futuless and Bake (2010) reported higher yield of cowpea planted in early August in the northern guinea savanna zone of Nigeria. Rekha and Singh (2015) in their work on anthracnose of sorghum reported higher yield for early sown sorghum. Sadeghi and Niyaki (2013) and Gaspar and Conley (2015) reported highest yield for early sown soyabean. Shailbala and Pundhir (2006) and Singh (2007) reported that the higher yields from potato cultivars were achieved when early planting dates were used.

Useni *et al.* (2014) in their work undertaken to study the effects of planting date and spacing on growth and production of cowpea reported that late sowing leads to slower growth and lower yield. This report is similar to the study undertaken in Turkey by Togay *et al.* (2014) who reported that delayed sowing significantly reduced the yield of cowpea seed. Shahzad *et al.* (2003) reported that late sowing of wheat reduces yield and was attributed to the characteristics of the crop being adversely affected by the late planting; this study was supported by Shahbazi *et al*. (2016) who also reported low yield on late sown wheat despite the low level of scab disease. Salehi *et al*. (2006) reported that delay in sowing led to decrease of grain yield. Board *et al.* (1999); Egli and Bruening (2000) and Kantolic and Slafer (2001) reported decreased yield in late sown soyabeans. Mousavi *et al.* (2005) reported that delay in planting red bean results in low yield. Delay in planting has been reported to affect both vegetative and reproductive growth, consequently affecting the yield (Mirzaienasab and Mojaddam, 2014). Mbong *et al*. (2012) suggested that any factor that positively or negatively affect grain yield of a plant would certainly have an influence on the yield obtained.

2.4 Effects of Scab Infection on Seed Quality

Seed is the most important agricultural input, and it is the basic unit for distribution and maintenance of plant population (Mugonozza, 2001). It carries the genetic potential of the crop plant and thus dictates the ultimate productivity of other inputs (Ashagre and Ermias, 2007). Seed quality depends on the genetic makeup of seeds and its interaction with the environment under which it is produced, harvested, processed and stored (Hampton, 2002; Begum *et al.* 2013). Higher physiological seed quality ensures healthy seedling establishment under wide range of environmental conditions (Copeland and McDonald, 2001). The physical parameters that are considered in seed quality include seed health, genetic purity, moisture content, physical purity, viability and vigour, seed size and appearance (Mallya, 1992; Schmit, 2000).

Seed vigour and viability are important characteristics of seed quality as they depict the ability of seed to germinate rapidly and produce normal seedling under a wide range of conditions (Cantliffe, 1998). It is the inherent attributes of a seed that determines its germination potential under optimal (laboratory) or field condition (Mbora *et al*., 2009). Seed vigor and viability not only influences the productivity but also the storability of seeds (Chhetri, 2009). Seed viability is determined by germination test which is used to provide information about the ability of seeds to develop into normal seedlings under optimal condition; nevertheless, it does not thoroughly clarify seed field emergence, which takes place under variable climatic conditions (Esechie *et al*., 2002). In order to predict seed emergence under field conditions, vigour tests are becoming increasingly popular tools that are routinely used to complement the results obtained by the germination test (Miguel *et al*., 2001). These tests among others include those that are based on resistance to stress (accelerated ageing and cold test) and the biochemical tests (electrical conductivity and tetrazolium tests) (Vieira and Krzyzanowski, 1999).

2.4.1 Germination test

This is the most used and acceptable indication of seed quality which provides farmers with the information related to the quality and storage capacity of the seed lot under optimal condition (ISTA, 1999; Copeland and McDonald, 2001). However, the result of the germination does not translate with the condition in the field (Milosevic *et al.*, 2010), hence the need for other tests to complement it (Hampton, 1999; Kolasinka *et al*., 2000; Esechie *et al*., 2002).

The germination of a seed lot can be negatively affected by the conditions the seeds are exposed to, both on the field and in storage (Egli *et al*., 2005). Begum *et al*. (2008) reported reduced germination percentage in soybean seeds inoculated with *Colletotrichum truncatum*. A reduction of 32.8 % was recorded in the germination of sunflower infected with *A. Helianthi* (Prasad and Kulshrestha, 1999). Mayhew and Caviness (1994) reported extreme low seed germination on soyabeans cultivar in Arkansas due to infection with *Phomopsis longicolla*. Nagaveni (2005) reported that due to environmental conditions, there was a decline in germination, vigour index and field emergence of onion seeds. Morsy *et al.* (2016) reported low germination of soyabeans produced from early planting while Sangakkara (1998) found that late establishment of cowpea produced high quality seed, as measured in terms of germination. This was supported by Akande *et al*. (2012) who reported better seed quality on late sown cowpea.

2.4.2 Electrical conductivity test

The electrical conductivity test is a measurement of electrolytes leaking from seeds (ISTA, 1995). It is based on the principle that less vigorous or deteriorated seeds have a slower rate of cell membrane repair during water uptake for germination, and therefore release greater amounts of solutes to the external environment (ISTA, 1995). Several factors can affect the results of the electrical conductivity test, such as the imbibition period, temperature, volume of water used, presence of damages on seed, seed size and genotype (Vieria *et al.,* 2002; Panobianco *et al.,* 2007). The interpretation of test result according to ISTA (2007):

0 - 25 $\mu Scm^{-1}g^{-1}$: seed has high vigour and suitable for early sowing, even under unfavourable conditions;

26 – 29 $\mu Scm^{-1}g^{-1}$: seed can be used for early sowing but has risk of poor performance under adverse conditions;

30 – 43 $\mu Scm^{-1}g^{-1}$: seed is not suitable for early sowing especially in unfavourable conditions;

43 $\mu Scm^{-1}g^{-1}$: seed has low vigour, therefore not suitable for sowing.

Seed-borne fungi plays an important role in seed deterioration (Pradhan *et al*., 2017) either due to damages caused by fungal infestation and colonization of tissues or by toxins produced by the fungi which are known to induce electrolyte leakage during seed imbibition (Lee-Stadelmann *et al.,* 1991; Mira *et al*., 2011). In a study conducted by Hampton *et al*. (1992), decline in germination and vigour of soybean seeds were reported to be directly proportional to the rise in solute leakage from the seeds; this corroborated the study by Galli *et al.* (2007) who reported that seed-borne pathogens reduced the physiological potential of soybean seed. There was a significant decrease in the seed vigour index of sunflower infected with *A. helianthi* (Prasad and Kulshiestha, 1999). It has also been recorded in sunflower that there was a low germination with less vigour index when infected by *Plasmopara halstedii* (Basavaraju *et al.,* 2004). Kundu and Kachari (2001) found that there was an increasing trend of electrolyte leakage with decline of germination percentage of *Cassia fistula* L. seeds. Chhetri (2009) reported high electrolyte leakage in low vigour rice seeds.

2.4.1.3 Accelerated ageing test

The accelerated ageing test is a stress test procedure developed by Delouche and Baskin (1973) to measure seed storability and evaluate vigour, that is, to assess the physiological potential of the seeds (Fanan *et al.,* 2006). The test involves the exposure of seeds to adverse levels of temperature (40-45ºC) and 100% relative humidity which are known to be the most important environmental factors that can cause rapid seed deterioration (Marco-Filho, 1999) for varying length of time followed by regular germination test (Chhetri, 2009). The basis for this test is that higher vigour seeds tolerate the high temperature-high humidity treatment and thus retain their capability to produce normal seedlings in the germination test (Lovato *et al.,* 2001; Baalbaki *et al.,* 2009; Marcos-Filho *et al.,* 2015).

Seed ageing have been attributed to factors, some of which include fungi attack, accumulation of toxin and degradation of membrane (Hussein *et al.,* 2011), with the two most important environmental factors influencing the rate of deterioration being relative humidity and temperature (McDonald, 1999; Anjorin and Mohammed, 2014) which in turn affect seed capability (Hussein *et al*., 2011). Seed deterioration is the loss of seed viability and vigour as a result of the effect of harsh condition (Kapoor *et al*., 2011); the process starts at physiological maturity and continues through harvest and storage and characterized by obvious decrease in germination, weak seedlings, loss of vigour and even seed death (Tilebeni and Golpayegani, 2011). Hussein *et al*. (2011) reported that ageing due to increased relative humidity and temperature, resulted in progressive loss of seed viability and vigour of sunflower. Begum *et al*. (2013) reported that pathogenic fungi severely affect seed vigour during storage leading to rapid deterioration and this was corroborated by Ushamalini *et al*. (1998) who reported reduced biochemical activities in stored cowpea seeds due to seed borne fungi. Iqbal *et al.* (2012) in their study on cotton reported that ageing have damaging effect on the enzymes that are necessary to convert reserve food in the embryo to usable form and ultimately production of normal seedlings. Bailly *et al.* (1996) reported that deterioration of sunflower seed during accelerated ageing test is closely related to a decrease in the activities of detoxifying enzymes and lipid peroxidation. Malaker *et al.* (2008) reported reduced vigour in wheat seed as a result of being infected by *Aspergillus* spp. Nargund *et al.* (2003) reported the presence of fungi in stored seeds which caused a reduction in germination percentage and vigour index.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Determination of Effects of Sowing Date on Scab Infection on Five Cowpea Varieties.

The experiment was conducted at the Institute for Agricultural Research (IAR) farm, Samaru, Zaria, in the Northern Guinea Savannah of Nigeria in August, 2016. Three of the varieties, SAMPEA 6, SAMPEA 8, SAMPEA 11 were obtained from IAR, while TVx 3236, and Ife Brown from IITA. The varieties have the following characteristics: SAMPEA 6 is late maturing variety, large white seed with black eye and rough seed coat texture; SAMPEA 8 is extra - early maturing, white seeded, and tolerant to major insect pests; SAMPEA 11 is dual purpose, resistant to septoria leaf spot, scab, nematodes and aphid (IAR Released Variety Descriptors, 2015). TVx 3236 is small seeded, creamy-brown with wrinkled seed coat; Ife Brown is brown seeded with wrinkled seed coat (Henshaw, 2008).

The field was sprayed with glyphosate (Glyview®, Nanjing No1 pesticides Co. Limited, Shanghai, China) at the rate of 4 L/ha and 14 days after, ploughed, harrowed and ridged. Prior to planting, single super phosphate (26 % P) and NPK (15:15:15) were broadcast at recommended rate of 30 kg/ha and 15 kg/ha, respectively (27 g/plot and 13.5 g/plot, respectively). The five varieties were sown at three dates of 10 days interval: August 9, 19 and 29 at two seeds per hole, 20 cm apart on the 0.75 m ridge, laid out as Randomized Complete Block Design (RCBD) with three replicates. The total plots were forty-five with each plot consisting of four ridges, each 3 m long at 0.75 m spacing. The plots were weeded twice at 4 and 8 weeks after sowing (WAS). Insect infestation was managed through foliar application of cypermethrin and dimethoate (Best action®, Modern insecticide Limited, Punjab, India) at 1 L/ha. There were no fungicidal applications.

Germination count was recorded at 2 WAS and starting at 21 days after sowing (DAS), incidence and severity of scab on the different plant parts (leaves, stems, peduncles, flower cushions and pods) were assessed on 10 plants, on the two central ridges at weekly interval for 10 weeks until harvest. Disease incidences were recorded and percentage calculated:

$$\text{Disease Incidence (\%)} = \frac{\text{Number of plants infected}}{\text{Total number of plants}} \times 100$$

Disease severity on plants parts (leaves, stems, peduncle flower cushions, and pods) on the two central ridges were assessed using assessment scale (1-10) as described by Emechebe (1981) and modified by Alabi (2016):

Scab on leaf

0 No symptoms
2 1 to 20 % of leaves with shot holes
4 21 to 40% of leaves with shot holes
6 41 to 60 % of leaves with large shot holes
8 61 to 80 % of leaves with large coalescing shot hole
10 Above 80 % of leaves with shot holes and marked leaf distortion

Scab on stem

0 No symptoms
2 1 to 20 % of scattered pin point lesions on lower stem
4 21 to 40% of scattered small lesions spreading up
6 41 to 60 % of extensive scabbing of young stem
8 61 to 80 % of stem lesions coalescing, covering also the branches
10 Above 80 % of severely damaged stem with marked stunting

Scab on peduncle

0 No symptoms
2 1 to 20 % of scattered pin point lesions on lower peduncle
4 21 to 40% of scattered small lesions spreading up peduncle
6 41 to 60 % of extensive scabbing of young peduncle
8 61 to 80 % of peduncle lesions coalescing, covering also flower cushions
10 Above 80 % of severely damaged peduncle with marked stunting

Scab on flowering cushions

0 No symptoms
2 1 to 20 % of scattered lesions on flowering cushions
4 21 to 40% of numerous, small lesions on flowering cushions
6 41 to 60 % of large lesions on older flowering cushions
8 61 to 80 % of large lesions on young cushions not associated with floral abortion

10 Above 80 % of large coalescing lesions with abortion of flower and/or pods

Scab on pod

0 No symptoms
2 1 to 20 % of scattered minute lesions on older pods
4 21 to 40% of scattered small lesions on most pods
6 41 to 60 % of extensive discrete scabbing of young pods
8 61 to 80 % of large, numerous coalescing lesions on pods
10 Severe scabbing of pods with shrivelling and mummification of old and/or abscission of young pods

The disease severity was calculated thus:

$$\text{Disease Severity} = \frac{\text{Sum of disease rating}}{\text{Maximum disease score x Total number of plants rated}} \text{ x } 100$$

Yield and yield parameters

The plants were harvested in the third and fourth week of November. Pods of each variety were handpicked into separate properly labelled sack, taking into consideration the sowing dates and replications. Pod weight per plot was recorded and after threshing, seed weight per plot was recorded and yield per hectare calculated.

3.2 Determination of Effects of Scab Infection on Seed Quality as influenced by Different Sowing Dates

The seeds were kept at room temperature in the laboratory after harvesting and threshing. A week later, germination and accelerated ageing tests were conducted in the Legumes Pathology laboratory of Department of Crop Protection Department, ABU, Zaria while electrical conductivity test was conducted at National Agricultural Seeds Council laboratory, Sheda, Abuja.

3.2.1 Germination test

One hundred (100) seeds of the harvested cowpea in four replicates totalling 400 seeds per variety were sown in plastic pots filled with river sand with holes perforated at the base to drain excess water as described in ISTA rules. The germination count was recorded on the 4^{th} and 7^{th} day after planting. The percent germination was calculated using the formula by ISTA (2007).

$$\text{Germination (\%)} = \frac{\text{Number of germinated seeds}}{\text{Total seeds planted}} \times 100$$

3.2.2 Electrical conductivity test

Electrical conductivity was determined using fifty (50) weighed cowpea seeds in four (4) replicates totalling 200 seeds for each variety. The seeds were soaked for 24 hours in a covered beaker containing 250 ml sterile distilled water (SDW) at a temperature of 20 °C, gently swirled to ensure all seeds were completely immersed; two flasks each containing only SDW with known conductivity were set aside as control. An electrical conductivity meter was used to measure the conductivity of the seed by inserting the conductivity dip cell into the seed-soaked solution, without allowing it touch the seeds until a stabilized reading was achieved and recorded. The conductivity dip cell was rinsed twice between each sample measurement (ISTA, 2007). Conductivity was calculated using the formula:

$$\textbf{Conductivity } (\mu Scm^{-1}g^{-1}) = \frac{\text{Bulk conductivity – Initial conductivity of water}}{\text{Initial weight of seed samples before soaking}}$$

Where:

Bulk conductivity = conductivity reading gotten from the SDW containing soaked seeds

Initial conductivity of water = mean of the conductivity of SDW in the two flasks that served as control

3.2.3 Accelerated ageing test

One hundred (100) cowpea seeds in four replicates totalling 400 seeds per variety were used. The seeds distributed in a single layer over a mesh fixed inside the crystal polyethylene box (Gerbox® type); containing 40 ml of sterile distilled water. The box containing the seeds was placed in the oven at a temperature of 41°C for 72 hours. After exposure period, the seeds were subjected to the germination test using the procedure described above.

3.3 Analysis of Data

Data obtained were subjected to analysis of variance (ANOVA) using SAS software version 9. Mean separation was done using Student Newman Keuls Test (SNK) at 5% level of probability.

CHAPTER FOUR

4.0 RESULTS

4.1 Effects of Sowing Dates on Incidence and Severity of Scab on Cowpea Leaf

Scab lesions were observed on all the plant parts above ground (Plates I to V). The effects of sowing dates on incidence and severity of scab are presented in Table 1. Incidence of scab on leaves at 4, 8 and 12 weeks after sowing (WAS) was significantly lower ($P \leq 0.05$) on TVx 3236 compared with other varieties. At 4 WAS, the incidence 21.11 %, was highest on Ife Brown but this was not significantly different ($P \geq 0.05$) from SAMPEA 6, SAMPEA 8 and SAMPEA 11. At 8 and 12 WAS, the incidence in SAMPEA 6, SAMPEA 8 and Ife Brown were not significantly different ($P \geq 0.05$) from one another but was significantly higher ($P \leq 0.05$) compare with SAMPEA 11 and TVx 3236. The three sowing dates were significantly different ($P \leq 0.05$) from one another, in that the third sowing date, 29th August had no record of scab infection, followed by 19th August which had lower incidence than 9th August with record of highest incidence, 68 %. The interaction of variety and sowing date on incidence of scab on leaf at 4, 8 and 12 WAS were significant ($P \leq 0.05$).

Severity of scab on leaves at 4 WAS was significantly lower ($P \leq 0.05$) on TVx 3236 compared with other varieties except SAMPEA 11. The highest severity was recorded in Ife Brown and this was not significantly different ($P \geq 0.05$) from those of SAMPEA 6 and SAMPEA 8. At 8 and 12 WAS, the trend was similar as severity in SAMPEA 6, SAMPEA 8 and Ife Brown were not significantly different ($P \geq 0.05$) from one another but significantly higher compared with those of SAMPEA 11 and TVx 3236. The severity of scab on leaf for the different sowing dates was significantly different ($P \leq 0.05$). At 4 WAS, severity on crops planted on 9th and 19th August were significantly higher ($P \leq 0.05$) compare with the August 29th planting.

Plate I: Scab on stem and peduncle

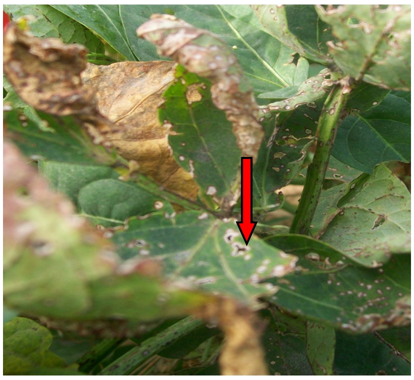

Plate II: Scab on leaves

Plate III: Scab on the pod

Plate IV: Mummified pod

Plate V: Infected pod with shrivelled seed

Table 1: Effects of Sowing Dates on Incidence and Severity of Scab on Leaf of Five Cowpea Varieties at Samaru, 2016

	Incidence of scab on leaf (%) at:			**Severity of scab on leaf (%) at:**		
	4 WAS	8 WAS	12 WAS	4 WAS	8 WAS	12 WAS
Variety						
SAMPEA 6	18.89^{a}	43.33^{a}	48.89^{a}	8.56^{ab}	14.67^{a}	21.78^{a}
SAMPEA 8	14.44^{a}	34.44^{a}	41.11^{ab}	8.56^{ab}	13.89^{a}	21.00^{a}
SAMPEA 11	11.11^{a}	24.44^{b}	31.11^{b}	7.78^{bc}	10.22^{b}	13.56^{b}
TVx 3236	1.11^{b}	14.44^{c}	16.67^{c}	6.78^{c}	8.78^{b}	9.44^{b}
Ife Brown	21.11^{a}	36.67^{a}	47.78^{a}	9.89^{a}	14.56^{a}	19.22^{a}
SE$\pm$	3.36	3.23	3.52	0.44	1.10	1.73
Sowing Date						
Aug. 9	20.67^{a}	55.33^{a}	68.00^{a}	12.73^{a}	20.33^{a}	29.07^{a}
Aug. 19	19.33^{a}	36.67^{b}	43.33^{b}	12.20^{a}	16.93^{b}	21.93^{b}
Aug. 29	0.00^{b}	0.00^{c}	0.00^{c}	0.00^{b}	0.00^{c}	0.00^{c}
SE$\pm$	2.61	2.50	2.72	0.34	0.85	1.34
Interaction						
Variety*Sowing Date	**	**	**	**	**	**

Means with the same superscript in a column are not significantly different at 5 % and 1 % level of significance ($P \leq 0.05$) using Student Newmans Keul Test (SNK)

WAS = weeks after sowing SE$\pm$ = standard error
*/** = significant at $P \leq 0.05$ and $P \leq 0.01$

At 8 and 12 WAS, severity was significantly higher on the 9th August, followed by 19th August while 29th August had no record of scab infection. The interaction of variety and sowing date on severity of scab at 4, 8 and 12 WAS was significant ($P \leq 0.05$).

4.1.1 Interaction of variety and sowing date on incidence and severity of scab on cowpea leaf

Table 2 shows interaction of variety and sowing date on incidence of scab on leaf. The varieties sown on 29th August showed no infection. Incidence of scab on TVx 3236 was significantly lower ($P \leq 0.05$) for 9th and 19th August. Incidence (96.67 %) recorded for Ife Brown sown on 9th August was significantly higher ($P \leq 0.05$); for SAMPEA 6 sown on 19th August, the trend was similar. For the varieties, SAMPEA 6, SAMPEA 11 and TVx 3236, the first and second sowing dates were statistically similar ($P \geq 0.05$) while for SAMPEA 8 and Ife Brown, the three sowing dates were significantly different ($P \leq 0.05$).

The interaction of variety and sowing date on scab severity on leaf are shown in Table 3. The varieties sown on the third sowing date showed no scab infection. Scab severity was significantly lower ($P \leq 0.05$) on TVx 3236 for the other two sowing dates. Highest severity for the first sowing date was recorded in Ife Brown, followed by SAMPEA 6 and SAMPEA 8 while for the second sowing date, highest severity was recorded in SAMPEA 6. For the varieties, SAMPEA 6, SAMPEA 8 and SAMPEA 11, the first and second sowing dates were statistically at par ($P \geq 0.05$), however, for SAMPEA 11, the second and third sowing dates were also similar. The three sowing dates were statistically similar ($P \geq 0.05$) for TVx 3236 while for Ife Brown, they were significantly different ($P \leq 0.05$).

Table 2: Interaction of Variety and Sowing Date on Incidence of Scab on Leaf of Five Cowpea Varieties at Samaru, 2016

4 WAS

Variety	Sowing Dates:		
	August 9	August 19	August 29
SAMPEA 6	13.33[bcd]	43.33[a]	0.00[d]
SAMPEA 8	23.33[b]	20.00[bc]	0.00[d]
SAMPEA 11	16.67[bcd]	16.67[bcd]	0.00[d]
TVx 3236	0.00[d]	3.33[cd]	0.00[d]
Ife Brown	50.00[a]	13.33[bcd]	0.00[d]
SE±	**5.83**		

8 WAS

Variety	Sowing Dates:		
	August 9	August 19	August 29
SAMPEA 6	70.00[a]	60.00[a]	0.00[d]
SAMPEA 8	66.67[a]	36.67[bc]	0.00[d]
SAMPEA 11	40.00[b]	33.33[bc]	0.00[d]
TVx 3236	23.00[bc]	20.00[c]	0.00[d]
Ife Brown	76.67[a]	33.33[bc]	0.00[d]
SE±	**5.59**		

12 WAS

Variety	Sowing Dates:		
	August 9	August 19	August 29
SAMPEA 6	80.00[ab]	66.67[bc]	0.00[g]
SAMPEA 8	76.00[b]	46.67[de]	0.00[g]
SAMPEA 11	53.33[cd]	36.67[def]	0.00[g]
TVx 3236	30.00[ef]	20.00[f]	0.00[g]
Ife Brown	96.67[a]	46.67[de]	0.00[g]
SE±	**6.09**		

Means with the same superscript in a column are not significantly different at 5 % and 1 % level of significance ($P \leq 0.05$) using Student Newmans Keul Test (SNK)

WAS = weeks after sowing SE± = standard error

Table 3: Interaction of Variety and Sowing Date on Severity of Scab on Leaf of Five Cowpea Varieties at Samaru, 2016

4 WAS

Variety	Sowing Dates:		
	August 9	August 19	August 29
SAMPEA 6	11.33[bc]	14.33[b]	0.00[d]
SAMPEA 8	12.33[bc]	13.33[bc]	0.00[d]
SAMPEA 11	11.67[bc]	11.67[bc]	0.00[d]
TVx 3236	10.00[c]	10.33[c]	0.00[d]
Ife Brown	18.33[a]	11.33[bc]	0.00[d]
SE±	**0.75**		

8 WAS

Variety	Sowing Dates:		
	August 9	August 19	August 29
SAMPEA 6	21.00[bcd]	23.00[b]	0.00[e]
SAMPEA 8	22.00[bc]	19.67[bcd]	0.00[e]
SAMPEA 11	16.00[bcd]	14.67[bcd]	0.00[e]
TVx 3236	13.00[d]	13.33[d]	0.00[e]
Ife Brown	29.67[a]	14.00[cd]	0.00[e]
SE±	**1.91**		

12 WAS

Variety	Sowing Dates:		
	August 9	August 19	August 29
SAMPEA 6	33.33[ab]	32.00[ab]	0.00[e]
SAMPEA 8	34.33[ab]	28.67[abc]	0.00[e]
SAMPEA 11	23.00[bcd]	17.67[cd]	0.00[e]
TVx 3236	15.00[d]	13.33[d]	0.00[e]
Ife Brown	39.67[a]	18.00[cd]	0.00[e]
SE±	**2.99**		

Means with the same superscript in a column are not significantly different at 5 % and 1 % level of significance ($P \leq 0.05$) using Student Newmans Keul Test (SNK)

WAS = weeks after sowing SE± = standard error

4.2 Effects of Sowing Dates on Incidence and Severity of Scab on Cowpea Stem

Results of effects of sowing dates on incidence and severity of scab on stem of five varieties of cowpea are presented in Table 4. At 4 WAS, the lowest incidence was recorded in TVx 3236 while highest incidence was recorded in Ife Brown, which was statistically similar ($P \geq 0.05$) to SAMPEA 8. At 8 and 12 WAS, the lowest incidence was recorded in TVx 3236. SAMPEA 8 had the highest incidences which were not different from those of SAMPEA 6 and Ife Brown, but were significantly higher ($P \leq 0.05$) compared with those of SAMPEA 11 and TVx 3236. The three sowing dates significantly differed ($P \leq 0.05$) from one another in which the first sowing date had the highest incidence of stem scab (80.00 %) followed by the second sowing date while the third sowing date showed no infection. The interaction of variety and sowing date on the incidence of scab on stem was significant ($P \leq 0.05$) at 4, 8 and 12 WAS.

For severity of scab on stem; at 4 WAS, the lowest severity was recorded in TVx 3236 while Ife brown recorded highest severity which was significantly higher ($P \leq 0.05$) compared with other varieties. At 8 and 12 WAS, TVx 3236 recorded the lowest severity while SAMPEA 8 recorded the highest severity of scab on stem. The three sowing dates differed ($P \leq 0.05$) from one another. Plants sown on the third sowing date showed no infection, followed by the second sowing date with lower severity while the first sowing date recorded highest severity of 42.40 % on the plants. The interaction of variety and sowing date on severity of scab on stem were significant ($P \leq 0.05$) at 4, 8 and 12 WAS.

Table 4: Effects of Sowing Dates on Incidence and Severity of Scab on Stem of Five Cowpea Varieties at Samaru, 2016

	Incidence of scab on stem (%) at:			**Severity of scab on stem (%) at:**		
	4 WAS	8 WAS	12 WAS	4 WAS	8 WAS	12 WAS
Variety						
SAMPEA 6	12.22^{b}	41.11^{a}	54.44^{a}	7.89^{bc}	12.67^{b}	28.11^{a}
SAMPEA 8	23.33^{a}	46.67^{a}	56.67^{a}	9.44^{b}	20.67^{a}	29.00^{a}
SAMPEA 11	11.11^{b}	30.00^{b}	37.78^{b}	8.00^{bc}	12.00^{b}	17.78^{b}
TVx 3236	1.11^{b}	13.33^{c}	25.56^{c}	6.78^{c}	8.00^{b}	11.00
Ife Brown	27.78^{a}	45.56^{a}	55.56^{a}	10.78^{a}	18.56^{a}	27.44^{a}
SE±	3.26	3.66	3.31	0.46	1.40	2.23
Sowing Date						
Aug. 9	23.33^{a}	62.00^{a}	80.00^{a}	13.13^{a}	23.93^{a}	42.40^{a}
Aug. 19	22.00^{a}	44.00^{b}	58.00^{b}	12.60^{a}	19.20^{b}	25.60^{b}
Aug. 29	0.00^{b}	0.00^{c}	0.00^{c}	0.00^{b}	0.00^{c}	0.00^{c}
SE±	2.52	2.83	2.56	0.36	1.08	1.73
Interaction						
Variety*Sowing Date	**	**	**	**	**	**

Means with the same superscript in a column are not significantly different at 5 % and 1 % level of significance (P ≤ 0.05) using Student Newmans Keul Test (SNK)

WAS = weeks after sowing   SE± = standard error
*/** = significant at P≤0.05 and P≤0.01

4.2.1 Interaction of variety and sowing date on incidence and severity of scab on cowpea stem

The interaction between variety and sowing date on the incidence of scab on stem of cowpea is presented in Table 5. There was no record of scab infection on plants sown at the third sowing date. For the first and second sowing dates, TVx 3236 recorded the lowest incidence of scab on stem. For the second sowing date, highest incidence was lower, 70 % in SAMPEA 6 and SAMPEA 8 when compared with the first sowing date which had highest incidence of 100 % for SAMPEA 8 and Ife brown. For varieties, SAMPEA 6, SAMPEA 8 and Ife Brown, the three sowing dates were significantly different ($P \leq 0.05$) from one another. For SAMPEA 11 and TVx 3236, the first and second sowing dates were statistically at par ($P \geq 0.05$).

The interaction of variety and sowing date on severity of scab on the stem are presented in Table 6. There was no record of infection on the varieties for the third sowing date. The second sowing date had TVx 3236 with the lowest severity while SAMPEA 8 recorded the highest with 33.67 %; though lower than the first sowing date. For the first sowing date, the lowest value of 18.33% was recorded in TVx 3236 while highest interaction on the severity of stem scab of 59.33 % in Ife Brown. The three sowing dates were significantly different ($P \leq 0.05$) from one another for SAMPEA 6, SAMPEA 8 and Ife Brown. There was no significant difference ($P \geq 0.05$) in severity of scab on stem for SAMPEA 11 and TVx 3236 in the first and second sowing dates.

Table 5: Interaction of Variety and Sowing Date on Incidence of Scab on Stem of Five Cowpea Varieties at Samaru, 2016

4 WAS

Variety	Sowing Dates:		
	August 9	August 19	August 29
SAMPEA 6	16.67^{de}	20.00^{cd}	0.00^{e}
SAMPEA 8	40.00^{ab}	30.00^{bc}	0.00^{e}
SAMPEA 11	6.67^{de}	26.67^{bc}	0.00^{e}
TVx 3236	0.00^{e}	3.33^{e}	0.00^{e}
Ife Brown	53.33^{a}	30.00^{bc}	0.00^{e}
SE±	**5.64**		

8 WAS

Variety	Sowing Dates:		
	August 9	August 19	August 29
SAMPEA 6	73.33^{a}	50.00^{b}	0.00^{d}
SAMPEA 8	90.00^{a}	50.00^{b}	0.00^{d}
SAMPEA 11	40.00^{b}	50.00^{b}	0.00^{d}
TVx 3236	20.00^{c}	20.00^{c}	0.00^{d}
Ife Brown	86.67^{a}	50.00^{b}	0.00^{d}
SE±	**6.34**		

12 WAS

Variety	Sowing Dates:		
	August 9	August 19	August 29
SAMPEA 6	93.33^{a}	70.00^{b}	0.00^{e}
SAMPEA 8	100.00^{a}	70.00^{b}	0.00^{e}
SAMPEA 11	63.33^{bc}	50.00^{cd}	0.00^{e}
TVx 3236	43.33^{d}	33.33^{d}	0.00^{e}
Ife Brown	100.00^{a}	66.67^{bc}	0.00^{e}
SE±	**5.73**		

Means with the same superscript in a column are not significantly different at 5 % and 1 % level of significance ($P \leq 0.05$) using Student Newmans Keul Test (SNK)

WAS = weeks after sowing SE± = standard error

Table 6: Interaction of Variety and Sowing Date on Severity of Scab on Stem of Five Cowpea Varieties at Samaru, 2016

4 WAS

Variety	Sowing Dates:		
	August 9	August 19	August 29
SAMPEA 6	11.67[bcd]	12.00[bcd]	0.00[e]
SAMPEA 8	14.00[bc]	14.33[b]	0.00[e]
SAMPEA 11	10.67[cd]	13.33[bcd]	0.00[e]
TVx 3236	10.00[d]	10.33[d]	0.00[e]
Ife Brown	19.33[a]	13.00[bcd]	0.00[e]
SE±	**0.80**		

8 WAS

Variety	Sowing Dates:		
	August 9	August 19	August 29
SAMPEA 6	15.67[bc]	22.33[bc]	0.00[d]
SAMPEA 8	38.3 [a]	23.67[b]	0.00[d]
SAMPEA 11	17.00[bc]	19.00[bc]	0.00[d]
TVx 3236	12.00[c]	12.00[c]	0.00[d]
Ife Brown	36.67[a]	19.00[bc]	0.00[d]
SE±	**2.43**		

12 WAS

Variety	Sowing Dates:		
	August 9	August 19	August 29
SAMPEA 6	52.00[a]	32.00[b]	0.00[d]
SAMPEA 8	53.33[a]	33.67[b]	0.00[d]
SAMPEA 11	29.00[bc]	24.33[bc]	0.00[d]
TVx 3236	18.33[bc]	14.67[cd]	0.00[d]
Ife Brown	59.33[a]	23.00[bc]	0.00[d]
SE±	**3.87**		

Means with the same superscript in a column are not significantly different at 5 % and 1 % level of significance ($P \leq 0.05$) using Student Newmans Keul Test (SNK)

WAS = weeks after sowing SE± = standard error

4.3 Effects of Sowing Dates on Incidence and Severity of Scab on Cowpea Peduncle

Table 7 shows the effects of sowing date and variety on scab on peduncle of cowpea. The incidence and severity of scab on the peduncle varied with the varieties and sowing. For incidence of scab on peduncle, at 12 WAS showed that incidence was significantly lower ($P \leq 0.05$) in TVx 3236 compared with the other varieties. The highest incidence was recorded on SAMPEA 6 and Ife Brown which was statistically similar ($P \geq 0.05$) to SAMPEA 8 and SAMPEA 11. There was significance difference ($P \leq 0.05$) among the sowing dates, with the third sowing date showing no infection while highest incidence of scab on peduncle of the plants recorded for the first sowing date. The interaction of variety and sowing date on incidence of scab on peduncle was significantly different ($P \leq 0.05$) at 12 WAS.

For effects of sowing dates on the severity of scab on peduncle of five varieties of cowpea, at 8 WAS, severity was significantly lower ($P \leq 0.05$) in TVx 3236 compared with other varieties except SAMPEA 6. The highest severity was recorded on Ife Brown, though statistically similar ($P \geq 0.05$) to SAMPEA 6, SAMPEA 8 and SAMPEA 11. At 12 WAS, TVx 3236 recorded the lowest severity, though not significantly different ($P \geq 0.05$) from SAMPEA 6 and SAMPEA 11 while SAMPEA 8 had the highest scab severity. Plants sown on the third sowing date had no record of scab infection. This was not significantly different ($P \geq 0.05$) from the second sowing date while the first sowing date, being significantly different ($P \leq 0.05$) from the other two sowing dates, recorded the highest scab severity on peduncle of the plants. The interaction of variety and sowing date on severity of scab on peduncle was not significantly different ($P \geq 0.05$) at 4, 8 and 12 WAS.

Table 7: Effects of Sowing Dates on Incidence and Severity of Scab on Peduncle of Five Cowpea Varieties at Samaru, 2016

	Incidence of scab on peduncle (%) at:			**Severity of scab on peduncle (%) at:**		
	4 WAS	8 WAS	12 WAS	4 WAS	8 WAS	12 WAS
Variety						
SAMPEA 6	0.00	18.89	36.67[a]	0.00[c]	8.78[ab]	10.78[ab]
SAMPEA 8	6.67	22.22	34.44[a]	7.33[a]	10.00[a]	15.00[a]
SAMPEA 11	0.00	21.11	26.67[a]	6.67[b]	9.67[a]	10.89[ab]
TVx 3236	0.00	8.89	13.33[b]	0.00[c]	7.56[b]	8.44[b]
Ife Brown	0.00	22.22	36.67[a]	0.00[c]	10.67[a]	14.78[a]
SE±	1.72	3.30	4.20	0.17	0.59	1.56
Sowing Date						
Aug. 9	4.00	4.00	66.00[a]	4.40[a]	16.13[a]	22.60[a]
Aug. 19	0.00	0.00	22.67[b]	4.00[b]	11.87[b]	13.33[b]
Aug. 29	0.00	0.00	0.00[c]	0.00[c]	0.00[c]	0.00[b]
SE±	1.33	1.33	3.25	0.13	0.45	1.21
Interaction						
Variety*Sowing Date	NS	NS	**	NS	NS	NS

Means with the same superscript in a column are not significantly different at 5 % and 1 % level of significance (P ≤ 0.05) using Student Newmans Keul Test (SNK)

WAS = weeks after sowing SE± = standard error
*/** = significant at P≤0.05 and P≤0.01
NS = not significant

4.3.1 Interaction of variety and sowing date on incidence of scab on cowpea peduncle

The interaction of variety and sowing date on incidence of scab on peduncle are presented in Table 8. At 12 WAS, there was no record of scab infection on the varieties for the third sowing date. The lowest incidence was recorded in TVx 3236 and this was not significantly different ($P \geq 0.05$) from those of SAMPEA 8, SAMPEA 6 and SAMPEA 11for the second sowing date. Incidence of scab was significantly higher in SAMPEA 6 compared with other varieties except Ife Brown and SAMPEA 8, for the first sowing date. The three sowing dates significantly differed ($P \leq 0.05$) from one another for the varieties, SAMPEA 6, SAMPEA 8, SAMPEA 11 and Ife Brown. For TVx 3236, the second and third sowing dates were statistically similar ($P \geq 0.05$).

4.4 Effects of Sowing Dates on Incidence and Severity of Scab on Cowpea Flower Cushion

Table 9 shows that effects of sowing dates on incidence and severity of scab on flower cushion of the plants. For incidence of scab on flower cushion at 5, 8 and 12 WAS, there was no significant difference among the varieties, though TVx 3236 had lowest incidence while SAMPEA 6 had the highest. The third sowing date, in spite of no record of scab infection was not significantly different ($P \geq 0.05$) from the second sowing date. However, incidence of scab on flower cushion of the plants was significantly higher ($P \leq 0.05$) in the first sowing date. The interaction of variety and sowing date on incidence of scab on flower cushion was not significant ($P \geq 0.05$).

The severity of scab on flower cushion showed that at 12 WAS, the lowest severity was recorded in TVx 3236 which was not significantly different ($P \geq 0.05$) from SAMPEA 8 and SAMPEA 11. Severity was significantly higher in SAMPEA 6, compared with other varieties except Ife Brown.

Table 8: Interaction of Variety and Sowing Date on Incidence of Scab on Peduncle of Five Cowpea Varieties at Samaru, 2016

12 WAS

Variety	Sowing Dates:		
	August 9	August 19	August 29
SAMPEA 6	86.67^{a}	23.33^{cd}	0.00^{e}
SAMPEA 8	70.00^{ab}	33.33^{c}	0.00^{e}
SAMPEA 11	56.67^{b}	23.33^{cd}	0.00^{e}
TVx 3236	33.33^{c}	6.67^{de}	0.00^{e}
Ife Brown	83.33^{a}	26.67^{cd}	0.00^{e}
SE±	**2.33**		

Means with the same superscript in a column are not significantly different at 5 % and 1 % level of significance ($P \leq 0.05$) using Student Newmans Keul Test (SNK)

WAS = weeks after sowing SE± = standard error

Table 9: Effects of Sowing Dates on Incidence and Severity of Scab on Flower Cushion of Five Cowpea Varieties at Samaru, 2016

	Incidence of scab on flower cushion (%) at:			**Severity of scab on flower cushion (%) at:**		
	5 WAS	8 WAS	12 WAS	5 WAS	8 WAS	12 WAS
Variety						
SAMPEA 6	0.00	6.67	20.00	0.00	7.44	16.22[a]
SAMPEA 8	4.44	13.33	16.67	7.11[a]	8.67	9.89[bc]
SAMPEA 11	0.00	4.44	7.78	6.67[a]	7.11	8.56[bc]
TVx 3236	0.00	5.56	5.56	0.00	7.22	7.22[c]
Ife Brown	0.00	10.00	16.67	0.00	7.89	13.00[ab]
SE±	1.99	3.94	4.93	0.20	0.56	1.48
Sowing Date						
Aug. 9	2.67	18.67[a]	31.33[a]	4.27[a]	12.47[a]	20.73[a]
Aug. 19	0.00	5.33[b]	8.67[b]	4.00[a]	10.53[b]	12.20[b]
Aug. 29	0.00	0.00[b]	0.00[b]	0.00[b]	0.00[c]	0.00[c]
SE±	1.54	3.05	3.82	0.15	0.44	1.15
Interaction						
Variety*Sowing Date	NS	NS	NS	NS	NS	**

Means with the same superscript in a column are not significantly different at 5 % and 1 % level of significance ($P \leq 0.05$) using Student Newmans Keul Test (SNK)

WAS = weeks after sowing SE± = standard error NS = not significant
** = significant at $P \leq 0.01$

The interaction of variety and sowing date on incidence of scab on flower cushion was significant ($P \leq 0.05$) at 12 WAS. For plants sown on the third sowing date, there was no record of scab infection on flower cushion, followed by the second sowing date with lower severity while for the first sowing date, severity was significantly higher ($P \leq 0.05$) on the flower cushion of the plants.

4.4.1 Interaction of variety and sowing date on severity of scab on cowpea flower cushion

The interaction of variety and sowing date on scab severity on flower cushions are shown in Table 10. There was no record of scab infection on plants sown on the third sowing date. The interaction in the second sowing date showed that severity was lower in TVx 3236 and this was not significantly different ($P \geq 0.05$) from other varieties, except SAMPEA 6. Furthermore, the interaction in the first sowing date revealed that severity was significantly lower ($P \leq 0.05$) in TVx 3236 compared to other varieties, except SAMPEA 11. Severity was significantly higher ($P \leq 0.05$) in SAMPEA 6 and this was not significantly different ($P \geq 0.05$) from Ife Brown. For the varieties, the three sowing dates were significantly different ($P \leq 0.05$) from one another for SAMPEA 6. For SAMPEA 11 and TVx 3236, they were statistically similar ($P \geq 0.05$). For SAMPEA 8, the first and second sowing dates were statistically similar ($P \geq 0.05$) while for Ife Brown, there was no significant difference ($P \geq 0.05$) between the second and third sowing dates.

Table 10: Interaction Effects of Variety and Sowing Date on Severity of Scab on Flower Cushion of Five Cowpea Varieties at Samaru, 2016

12 WAS

Variety	Sowing Dates:		
	August 9	August 19	August 29
SAMPEA 6	31.67[a]	17.00[b]	0.00[c]
SAMPEA 8	18.00[b]	11.67[bc]	0.00[c]
SAMPEA 11	14.67[bc]	11.00[bc]	0.00[c]
TVx 3236	11.33[bc]	10.33[bc]	0.00[c]
Ife Brown	28.00[a]	11.00[bc]	0.00[c]
SE±	**2.57**		

Means with the same superscript in a column are not significantly different at 5 % and 1 % level of significance ($P \leq 0.05$) using Student Newmans Keul Test (SNK)

WAS = weeks after sowing SE± = standard error

4.5 Effects of Sowing Dates on Incidence and Severity of Scab on Cowpea Pod

Table 11 shows the effects of sowing date on the incidence and severity of scab on pod of five varieties of cowpea. For incidence of scab, at 8 WAS, only SAMPEA 8 and Ife Brown showed infection with incidences of 2.22 % and 4.44 %, respectively although the differences were not significant ($P \geq 0.05$). At 10 and 12 WAS, incidence of scab on SAMPEA 8 was significantly higher ($P \leq 0.05$) compared with the other varieties. TVx 3236 had significantly lowest incidence although this was not different from the other varieties except SAMPEA 8. The incidence of scab on pod of the plants showed that the first sowing date had significantly higher ($P \leq 0.05$) incidence compared with the other two sowing dates. The interaction of variety and sowing date on incidence of scab on pod was significant at 10 and 12 WAS.

The severity of scab on pod of five varieties showed that at 12 WAS, severity was low on SAMPEA 11 and this was not significantly different ($P \geq 0.05$) from SAMPEA 8, TVx 3236 and Ife Brown. Severity was significantly higher ($P \leq 0.05$) on SAMPEA 6 compared with other varieties. The severity of scab on pod of the plants showed that the first sowing date had significantly higher ($P \leq 0.05$) severity compared with the other two sowing dates. The interaction of variety and sowing date on severity of scab on pod was significant ($P \leq 0.05$) at 8 and 10 WAS.

4.5.1 Interaction of variety and sowing date on incidence and severity of scab on cowpea pod

The interaction of variety and sowing date on incidence of scab on pod are shown in Table 12. At 10 WAS, interaction in the third sowing date, with no record of scab infection on the plants, were not significantly different ($P \geq 0.05$) from those of the other two sowing dates, except for first sowing date in SAMPEA 8 and Ife Brown. At 12WAS, the interaction showed that for the second sowing date, there was no record

Table 11: Effects of Sowing Dates on Incidence and Severity of Scab on Pod of Five Cowpea Varieties at Samaru, 2016

	Incidence of scab on pod (%) at:			**Severity of scab on pod (%) at:**		
	8 WAS	10 WAS	12 WAS	8 WAS	10 WAS	12 WAS
Variety						
SAMPEA 6	0.00	1.11^{b}	8.89^{ab}	0.00^{c}	7.22^{c}	18.11^{a}
SAMPEA 8	2.22	11.11^{a}	13.33^{a}	9.00^{b}	11.78^{ab}	14.22^{b}
SAMPEA 11	0.00	0.00^{b}	2.22^{b}	9.56^{b}	9.56^{bc}	10.22^{b}
TVx 3236	0.00	0.00^{b}	1.11^{b}	10.00^{b}	10.11^{abc}	10.56^{b}
Ife Brown	4.44	4.44^{b}	4.44^{b}	13.11^{a}	13.11^{a}	13.11^{b}
SE±	1.45	1.99	2.31	0.85	0.89	1.33
Sowing Date						
Aug. 9	3.33	8.67^{a}	14.00^{a}	9.27^{a}	11.60^{a}	17.33^{a}
Aug. 19	0.67	2.00^{b}	4.00^{b}	7.73^{a}	9.47^{b}	12.40^{b}
Aug. 29	0.00	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{c}	0.00^{c}
SE±	1.13	1.53	1.79	0.66	0.69	1.03
Interaction						
Variety*Sowing Date	NS	*	*	*	**	NS

Means with the same superscript in a column are not significantly different at 5 % and 1 % level of significance ($P \leq 0.05$) using Student Newmans Keul Test (SNK)

NS = not significant
WAS = weeks after sowing SE± = standard error
*/** = significant at $P \leq 0.05$ and $P \leq 0.01$

Table 12: Interaction Effects of Variety and Sowing Date on Incidence of Scab on Pod of Five Cowpea Varieties at Samaru, 2016

10 WAS

Variety	Sowing Dates:		
	August 9	August 19	August 29
SAMPEA 6	3.33^{b}	0.00^{b}	0.00^{b}
SAMPEA 8	26.67^{a}	6.67^{b}	0.00^{b}
SAMPEA 11	0.00^{b}	0.00^{b}	0.00^{b}
TVx 3236	3.33^{b}	0.00^{b}	0.00^{b}
Ife Brown	10.00^{a}	3.33^{b}	0.00^{b}
SE±	**3.44**		

12 WAS

Variety	Sowing Dates:		
	August 9	August 19	August 29
SAMPEA 6	16.67^{b}	10.00^{bc}	0.00^{c}
SAMPEA 8	33.33^{a}	6.67^{bc}	0.00^{c}
SAMPEA 11	6.67^{bc}	0.00^{c}	0.00^{c}
TVx 3236	3.33^{c}	0.00^{c}	0.00^{c}
Ife Brown	10.00^{bc}	3.33^{c}	0.00^{c}
SE±	**4.00**		

Means with the same superscript in a column are not significantly different at 5 % and 1 % level of significance ($P \leq 0.05$) using Student Newmans Keul Test (SNK)

WAS = weeks after sowing SE± = standard error

of scab infection on TVx 3236 and this was not significantly different from the other varieties in the first sowing date, except SAMPEA 6 and SAMPEA 8. For the varieties, SAMPEA 11, TVx 3236 and Ife Brown, the three sowing dates were statistically similar ($P \geq 0.05$) at 12 WAS.

Table 13 shows the interaction of variety and sowing date on the severity of scab on pod of cowpea. At 8 WAS, there was no scab infection on the third sowing date and this was not significantly different ($P \geq 0.05$) compared with the other two sowing dates in SAMPEA 6, SAMPEA 11 and TVx 3236. However, severity was significantly higher ($P \leq 0.05$) in Ife Brown for the first sowing date compared with other varieties and sowing dates. At 10 WAS, the interaction showed that the third sowing date, with no appearance of scab, was significantly lower ($P \leq 0.05$) compared with the first sowing date in the other varieties except SAMPEA 11. Severity was significantly higher ($P \geq 0.05$) in Ife Brown compared with other varieties and sowing dates. For the varieties, SAMPEA 6 and TVx 3236, the first and second sowing dates were not significantly different ($P \geq 0.05$). For SAMPEA 8, the first and second sowing dates were statistically similar ($P \geq 0.05$). For SAMPEA 11, the three sowing dates were not different ($P \geq 0.05$) from one another while for Ife Brown, the first sowing date was significantly higher ($P \leq 0.05$) compared with the other two sowing dates.

4.6 Effects of Sowing Dates and Scab Infection on Yield of Cowpea

The effect of sowing date and scab infection on germination count and yield of cowpea are presented in Table 14. There was no significant difference ($P \geq 0.05$) in the germination count amongst the varieties. Pod weight (kg/ha) in SAMPEA 6 was not significantly different ($P \geq 0.05$) from those of SAMPEA 8, SAMPEA 11 and Ife Brown but was significantly higher ($P \leq 0.05$) compared with TVx 3236 which had the lowest

Table 13: Interaction Effects of Variety and Sowing Date on Severity of Scab on Pod of Five Cowpea Varieties at Samaru, 2016

8 WAS

Variety	Sowing Dates:		
	August 9	August 19	August 29
SAMPEA 6	0.00^{c}	0.00^{c}	0.00^{c}
SAMPEA 8	8.67^{b}	8.33^{b}	0.00^{c}
SAMPEA 11	0.00^{c}	0.00^{c}	0.00^{c}
TVx 3236	0.00^{c}	0.00^{c}	0.00^{c}
Ife Brown	19.00^{a}	10.33^{bc}	0.00^{c}
SE±	**1.47**		

10 WAS

Variety	Sowing Dates:		
	August 9	August 19	August 29
SAMPEA 6	10.33^{bc}	0.00^{d}	0.00^{d}
SAMPEA 8	14.67^{ab}	10.67^{bc}	0.00^{d}
SAMPEA 11	0.00^{d}	0.00^{d}	0.00^{d}
TVx 3236	10.33^{bc}	0.00^{d}	0.00^{d}
Ife Brown	19.00^{a}	10.33^{bc}	0.00^{d}
SE±	**1.53**		

Means with the same superscript in a column are not significantly different at 5 % and 1 % level of significance ($P \leq 0.05$) using Student Newmans Keul Test (SNK)

WAS = weeks after sowing SE± = standard error

Table 14: Effects of Sowing Dates on Yield of Five Cowpea Varieties at Samaru, 2016

	Germ Count (%)	**100-Seed Weight (g)**	**Pod Weight (kg/Ha)**	**Seed Weight (kg/Ha)**
Variety				
SAMPEA 6	47.67	16[a]	2086.40[a]	1395.1
SAMPEA 8	46.33	15[a]	1938.30[ab]	1506.2
SAMPEA 11	46.11	15[a]	1925.90[ab]	1691.4
TVx 3236	45.44	11[c]	1493.80[b]	1296.3
Ife Brown	47.33	14[b]	1950.60[ab]	1456.8
SE±	1.36	0.39	142.18	111.66
Sowing Date				
Aug. 9	52.53[a]	14	2600.00[a]	1792.60[a]
Aug. 19	39.93[c]	14	1333.30[c]	1192.60[b]
Aug. 29	47.27[b]	14	1703.70[b]	1422.20[b]
SE±	1.06	0.30	110.13	86.49
Interaction				
Variety*Sowing Date	NS	NS	NS	NS

Means with the same superscript in a column are not significantly different at 5 % and 1 % level of significance (P ≤ 0.05) using Student Newmans Keul Test (SNK)

NS = not significant at 5 % and 1%
*/** = Significant at P≤0.05 or P≤0.01
WAS = weeks after sowing
SE± = standard error

yield. The yield in TVx 3236 was however not significantly different (P≥0.05) compared with SAMPEA 8, SAMPEA 11 and Ife Brown. The seed weight (Kg/ha) for the varieties was not significantly different (P≥0.05) though SAMPEA 11 had the highest while TVx 3236 had the lowest yield. For 100-seed weight, SAMPEA 6, SAMPEA 8 and SAMPEA 11 were not different (P≥0.05) from one another but were significantly higher (P≤0.05) compared with TVx 3236 and Ife Brown.

For sowing date, germination count was significantly higher (P≤0.05) in the first sowing date August 9, followed by August 29 and August 19. Pod weight (Kg/ha) was significantly higher (P≤0.05) in the first sowing date, August 9, followed by August 29 and August 19. Seed weight (Kg/ha) was significantly higher (P≤0.05) in the first sowing date, August 9 compared with the other two sowing dates which were not significantly different (P≥0.05) from each other. For 100 seed weight, the three sowing dates were not statistically different (P>0.05).

4.6.1 Correlation coefficients of scab infected plant parts with yield of cowpea

The correlation of scab on different plant parts with yield and yield components are as shown in Table 15. For 100 seed weight, correlation coefficients of yield with severity of scab on leaves, stem, peduncle and flower cushion was positive but not significant (P≥0.05) while on pod, it was negative and not significant (P≥0.05). For seed weight (Kg/Ha), correlation coefficients of yield with severity of scab on different plant parts was positive but only significant (P≥0.05) on the peduncle (r = 0.35828). For Pod weight (Kg/Ha), correlation coefficients of yield with severity of scab was highly significant (P≤0.01) on leaves, stems, peduncle and flower cushion (r = 0.41007, 0.42390, 0.55185 and 0.48785), respectively.

Table 15: Correlation Coefficients of Scab Infected Plant Parts with Yield of Five Cowpea Varieties at Samaru, 2016

	Scab on:							
	Leaf	Stem	Peduncle	Flower cushion	Pod	100seed wgt	Seed wgt/Ha	Pod wgt/Ha
Leaf Sv.	1.00000							
Stem Sv.	0.91420**	1.00000						
Peduncle Sv.	0.76430**	0.86505**	1.00000					
Flower cushion Sv.	0.64601**	0.79779**	0.83752**	1.00000				
Pod Sv.	0.49647**	0.56879**	0.66423**	0.66799**	1.00000			
100 seed weight	0.18410	0.16352	0.13090	0.14395	-0.10438	1.00000		
Seed wgt (Kg/ha)	0.10711	0.08174	0.35828*	0.17020	0.06015	0.33601*	1.00000	
Pod wgt (Kg/ha)	0.41007**	0.42390**	0.55185**	0.48785**	0.19043	0.33285*	0.772244**	1.00000

The coefficient must exceed 0.314 and 0.394 to be significant at 5 % and 1 % probability levels respectively

*/**= Significant at 5 % and 1 % level of significance
Wgt = Weight Sv = Severity

4.6.2 Path coefficient analysis and percent contribution of scab severity on yield of cowpea

The path analysis shows the interrelationship of scab severity on different plant parts and yield (Tables 16 and 17). The result indicated that the highest individual percent contribution obtained was from pod scab severity (18.94 %), followed by flower cushion and peduncle scab severity, being 16.42 % and 9.40 %, respectively while stem scab severity had lowest of 1.68 %. The highest positive combined contribution was from stem plus peduncle scab severity, 10.03 %, followed by peduncle plus flower cushion scab severity, 8.25 %. The percent contribution unaccounted for was 63.9 %. The direct and indirect contribution of scab infected plant parts on yield showed that the highest direct contribution to effects of scab severity on yield was from the stem scab severity (-0.435) which was negative, while peduncle, flower and pod scab showed a positive direct effect on yield. Leaf scab also had negative effects (-0.198). The highest indirect effects via other plant parts were on stem scab via peduncle, the least was pod scab via flower cushion.

Table 16: Percentage Contribution of Scab Severity on Different Plant Parts on Yield of Cowpea at Samaru, 2016

Seed weight per hectare	
Individual contribution	(%)
Leaf scab severity	3.90
Stem scab severity	1.68
Peduncle scab severity	9.40
Flower cushion scab severity	16.42
Pod scab severity	18.94
Combined contribution	
Leaf + stem scab severity	4.27
Leaf + peduncle scab severity	-4.55
Leaf + flower cushion scab severity	-4.02
Leaf + pod scab severity	-1.71
Stem + peduncle scab severity	10.03
Stem + flower cushion scab severity	-8.86
Stem + pod scab severity	-3.77
Peduncle + flower cushion scab severity	8.25
Peduncle + pod scab severity	3.51
Flower cushion + pod scab severity	2.66
RESIDUAL	63.91
TOTAL	**100**

Table 17: Direct and Indirect Effects of Scab Severity on the Different Plant Parts on Yield (Seed Weight per Hectare) of Cowpea, Samaru, 2016

	Direct and indirect effects of:					
Infected Plant Parts	Leaf scab	Stem scab	Peduncle scab	Flower cushion Sca b	Pod scab	Total effects
			Seed weight per hectare			
Leaf scab	**-0.198**[a]	0.216	0.204	0.204	0.087	0.107
Stem scab	-0.098	**-0.435**[a]	0.262	0.245	0.109	0.082
Peduncle scab	-0.132	-0.364	**0.130**[a]	0.076	0.351	0.060
Flower cushion scab	-0.131	-0.347	0.310	**0.307**[a]	0.032	0.170
Pod scab	-0.112	-0.281	-0.112	0.234	**0.405**[a]	0.358

[a] = Direct effect

4.7 Effects of Scab Infection on Seed Quality of Cowpea

Table 18 shows the results of germination, electrical conductivity and accelerated aging tests to determine effect of scab on seed quality. Germination test showed that Tvx 3236 had a significantly higher ($P \leq 0.05$) germination percentage compared with the other varieties while lowest germination percentage was recorded in Ife Brown. However, Ife Brown and SAMPEA 8 were not significantly different ($P \geq 0.05$) from each other.

The electrical conductivity test conducted showed no significance difference ($P \geq 0.05$) across all the varieties though the lowest value of 39.12 $\mu Scm^{-1}g^{-1}$ was recorded for TVx 3236 while SAMPEA 11 had the highest of 45.91 $\mu Scm^{-1}g^{-1}$. For the accelerated ageing test, the highest germination percentage was recorded in TVx 3236. This was not different from SAMPEA 11 but was significantly higher ($P \leq 0.05$) compared with the other varieties.

There was significant difference ($P \leq 0.05$) among the three sowing dates with respect to germination and accelerated ageing test while for electrical conductivity test, they were statistically the same. For germination test, the highest germination percentage of 90% was recorded for the third sowing date while the first sowing date had the lowest germination percentage of 67.20 %. For the electrical conductivity test, the first sowing date had the lowest conductivity score of 40.01 $\mu Scm^{-1}g^{-1}$ while the third sowing date had the highest of 44.40 $\mu Scm^{-1}g^{-1}$. For accelerated ageing test, the third sowing date had the highest germination percentage of 82.07 % after exposure to stress factor, while the first sowing date had the lowest germination percentage of 64.47 %. The interaction between variety and sowing date was highly significant ($P \leq 0.05$) for germination and accelerated ageing.

Table 18: Germination, Electrical Conductivity and Accelerated Ageing Tests on Five Cowpea Varieties to Determine Effects of Scab on Seed Quality

	Germination (%)	Electrical Conductivity ($\mu Scm^{-1}g^{-1}$)	Accelerated Ageing (%)
Variety			
SAMPEA 6	73.44^{c}	41.22	67.56^{b}
SAMPEA 8	68.22^{cd}	44.99	69.00^{b}
SAMPEA 11	87.89^{b}	45.41	80.22^{a}
TVx3236	94.44^{a}	39.12	80.44^{a}
Ife Brown	65.00^{d}	41.56	63.89^{b}
SE$\pm$	1.86	2.87	1.66
SowingDate			
Aug. 9	67.20^{c}	42.94	64.47^{c}
Aug. 19	76.20^{b}	40.01	70.13^{b}
Aug. 29	90.00^{a}	44.40	82.07^{a}
SE$\pm$	1.44	2.22	1.29
Significance			
Interaction			
Variety*Sowing Date	**	NS	**

Mean with the same superscript in a column are not significantly different at 5 % and 1 % level of significance using Student Newmans Keul test

SE$\pm$ = standard error
NS = not significant
*/**= Significant at 5 % and 1 % level of significance

4.7.1 Interaction of variety and sowing date on the germination and accelerated ageing tests

Results in Table 19 shows the interaction of variety and sowing date on the germination and accelerated ageing tests of five varieties of cowpea. For germination test, the highest germination percentage of 95.67 % was recorded on the second sowing date for the variety, TVx 3236 which was significantly higher ($P \leq 0.05$) compared with the other two sowing dates for SAMPEA 8, SAMPEA 6 and Ife Brown. The lowest germination was recorded on the variety, Ife Brown for the first sowing date. For accelerated ageing, highest germination was recorded on the variety, Ife Brown for the third sowing date which was not significantly different ($P \geq 0.05$) from the other two sowing dates for TVx 3236 and SAMPEA 11. Germination was significantly lower ($P \leq 0.05$) in Ife Brown for the first sowing date compared with other varieties and sowing dates.

The interaction on the varieties for both tests show that for SAMPEA 6, SAMPEA 8 and Ife Brown, the third sowing date was significantly higher ($P \leq 0.05$) compared with the other two sowing dates. For TVx 3236, the three sowing dates were statistically similar ($P \geq 0.05$) to one another. For SAMPEA 11, the first sowing date was significantly lower ($P \leq 0.05$) compared with the other two sowing dates for germination test, while for accelerated ageing test, the three sowing dates were statistically similar ($P \geq 0.05$) to one another.

Table 19: Interaction of Variety and Sowing Date on Germination and Accelerated Ageing Tests conducted to Determine Cowpea Seed Quality

Germination test

Variety	Sowing Dates:		
	August 9	August 19	August 29
SAMPEA 6	62.00^{d}	66.00^{d}	92.33^{a}
SAMPEA 8	62.67^{d}	61.33^{d}	80.67^{bc}
SAMPEA 11	85.33^{b}	86.67^{a}	91.67^{a}
TVx 3236	93.67^{a}	95.67^{a}	94.00^{a}
Ife Brown	32.33^{e}	71.33^{c}	91.33^{a}
SE±	**3.22**		

Accelerated Ageing test

Variety	Sowing Dates:		
	August 9	August 19	August 29
SAMPEA 6	61.33^{bc}	60.67^{bc}	80.67^{a}
SAMPEA 8	56.00^{c}	66.00^{b}	85.00^{a}
SAMPEA 11	79.67^{a}	81.33^{a}	79.67^{a}
TVx 3236	80.33^{a}	81.33^{a}	79.67^{a}
Ife Brown	45.00^{d}	61.33^{bc}	85.33^{a}
SE±	**2.88**		

Mean with the same superscript in a column are not significantly different at 5 % and 1 % level of significance using Student Newmans Keul test

SE± = standard error

4.7.2 Correlation coefficients of scab infected plant parts with seed quality of cowpea

The correlation of scab on different plant parts with seed quality tests are as shown in Table 20. For germination test, correlation coefficients with severity of scab on leaves, stem, peduncle, flower cushion and pod was negative and highly significant ($P \leq 0.01$) (r = -0.80493, -0.83207, -0.69688, -0.64851 and -0.536821), respectively. Electrical conductivity test showed a positive and highly significant correlation on flower cushion and pod severity respectively (r = 0.42605 and 0.43325, respectively), with germination test, it was negative and significant ($P \leq 0.05$) (r = -0.32984). The correlation of scab severity on different plant parts with accelerated ageing test showed a negative and highly significant ($P \leq 0.01$) correlation on the different plant parts; leaves, stem, peduncle, flower cushion and pod (r =-0.82949, -0.84788, -0.68836, -0.6394 and -0.48362, respectively) while correlation with electrical conductivity test showed a negative but not significant correlation (r = -0.22371). .

4.7.3 Path coefficient analysis and percent contribution of scab severity on different plant parts on seed quality of cowpea

The path analysis shows the interrelationship of scab severity on different plant parts and seed quality as presented in Tables 21 and 22. For germination test, the result indicated that the highest individual percent contribution obtained was from peduncle scab severity (19.38 %), followed by flower cushion and pod scab severity, being 10.66 % and 7.37 %, respectively while stem scab severity had the lowest. The highest positive combined contribution was from peduncle plus flower cushion scab severity, 9.55 %, followed by peduncle plus pod scab severity, 8.25 %. The percent contribution unaccounted for was 27.09 %.

Table 20: Correlation Coefficients of Scab Infected Plant Parts with Seed Quality Tests on Five Cowpea Varieties, Samaru, 2016

	Scab on:							
	Leaf	Stem	Peduncle	Flower cushions	Pod	Germination	Elect. Conduc.	Acc. ageing
Leaf Sv	1.00000							
Stem Sv	0.91420**	1.00000						
Peduncle Sv	0.76430**	0.86505**	1.00000					
Flower cushion Sv	0.64601**	0.79779**	0.83752**	1.00000				
Pod Sv	0.49647**	0.56879**	0.66423**	0.66799**	1.00000			
Germination test	-0.80493**	-0.83207**	-0.69688**	-0.64851**	-0.53681**	1.00000		
Elect. Conduc. test	0.24415	0.34317*	0.296924	0.42605**	0.43325**	-0.32984*	1.00000	
Acc. ageing test	-0.82949**	-0.84788**	-0.68836**	-0.63940**	-048362**	0.92696**	-0.22371	1.00000

The coefficient must exceed 0.314 and 0.394 to be significant at 5 % and 1 % probability levels respectively

*/**= Significant at 5 % and 1 % level of significance
Sv = Severity
Elect. Conduc. = electrical conductivity
Acc. Ageing = accelerated ageing

Table 21: Percentage Contribution of Scab Severity on Different Plant Parts on Germination (Viability) of Cowpea at Samaru, 2016

Germination	
Individual contribution	(%)
Leaf scab severity	2.83
Stem scab severity	0.06
Peduncle scab severity	19.38
Flower cushion scab severity	10.66
Pod scab severity	7.37
Combined contribution	
Leaf + stem scab severity	-0.20
Leaf + peduncle scab severity	4.21
Leaf + flower cushion scab severity	3.65
Leaf + pod scab severity	3.05
Stem + peduncle scab severity	-0.59
Stem + flower cushion scab severity	-0.51
Stem + pod scab severity	-0.43
Peduncle + flower cushion scab severity	9.55
Peduncle + pod scab severity	7.98
Flower cushion + pod scab severity	5.92
RESIDUAL	27.09
TOTAL	**100**

Table 22: Percentage Contribution of Scab Severity on Different Plant Parts on Seed Vigour of Cowpea at Samaru, 2016

Accelerated Ageing **Individual contribution**	(%)
Leaf scab severity	0.96
Stem scab severity	3.26
Peduncle scab severity	26.39
Flower cushion scab severity	19.54
Pod scab severity	12.42
Combined contribution	
Leaf + stem scab severity	-0.88
Leaf + peduncle scab severity	2.86
Leaf + flower cushion scab severity	2.87
Leaf + pod scab severity	2.30
Stem + peduncle scab severity	-5.27
Stem + flower cushion scab severity	-5.30
Stem + pod scab severity	-4.25
Peduncle + flower cushion scab severity	15.09
Peduncle + pod scab severity	12.10
Flower cushion + pod scab severity	7.50
RESIDUAL	7.50
TOTAL	**100**

For accelerated ageing test, the result indicated that the highest individual percent contribution obtained was from peduncle scab severity (26.39 %), followed by flower cushion and pod scab severity, being 19.54 % and 12.42 %, respectively while leaf scab severity had the lowest of 0.96 %. The highest positive combined contribution was from peduncle plus flower cushion scab severity, 15.09 %, followed by peduncle plus pod scab severity, 12.10 %. The percent contribution unaccounted for was 7.50 %.

4.7.4 Direct and indirect effects of scab severity on seed quality

The direct and indirect effects of scab infected plant parts on seed quality are shown in Table 23. The highest direct contribution to effects of scab severity on seed viability (germination) and vigour (accelerated ageing test) was from the peduncle scab severity (-0.440 and -0.514, respectively) which were negative, while stem scab showed a positive direct effect on seed quality. The least direct effects were on leaf scab. For viability, the highest indirect effects via other plant parts were on peduncle scab via stem, while for vigour, flower cushion scab via stem.

Table 23: Direct and Indirect Effects of Scab Infected Parts on Seed Quality, Samaru, 2016

	Direct and indirect effects of:					
Infected Plant Parts	Leaf scab	Stem scab	Peduncle scab	Flower cushion scab	Pod scab	Total effects
			Germination (viability)			
Leaf scab	**-0.168[a]**	0.012	-0.250	-0.217	-0.181	-0.805
Stem scab	-0.083	**0.024[a]**	-0.284	-0.261	-0.227	-0.832
Peduncle scab	-0.096	0.015	**-0.440[a]**	-0.120	-0.056	-0.697
Flower cushion scab	-0.112	0.188	-0.162	**-0.327[a]**	-0.068	-0.649
Pod scab	-0.112	0.020	-0.092	-0.081	**-0.271[a]**	-0.537
			Accelerated ageing (vigour)			
Leaf scab	**-0.098[a]**	-0.089	-0.292	-0.294	-0.235	-0.829
Stem scab	-0.049	**-0.180[a]**	-0.332	-0.353	-0.295	-0.848
Peduncle scab	-0.056	-0.117	**-0.514[a]**	-0.162	-0.073	-0.688
Flower cushion scab	-0.065	-0.144	-0.189	**-0.442[a]**	-0.088	-0.639
Pod scab	-0.065	-0.151	-0.107	-0.110	**-0.352[a]**	-0.484

[a] = Direct effect

CHAPTER FIVE

5.0 DISCUSSION

The results of this study showed that there was appearance of scab symptoms on all the above ground parts of the plants (Plate I to IV). This corroborates the study of Mbong *et al*. (2014) and Afutu *et al.* (2016) who reported scab symptoms on all the aboveground parts of the cowpea plants. There was progressive increase in the disease incidence and severity with increase in the age of the plants. This is in agreement with the report of Mbong *et al.* (2014).

The plants from seeds sown early on the 9th of August 2016 cowpea had the highest scab incidence and severity which may be attributed to environmental condition (Appendix II). Emechebe and Lagoke (2002) reported that environmental conditions conducive for disease development include high temperature and relative humidity. This study is in line with that conducted at Zaria by Mbong *et al.* (2010a) who reported that cowpea planted on July 26 for three cropping years (2004 to 2006) showed more infection from scab disease in comparison to late sown cowpea. Akande *et al.* (2012) also reported higher incidence and severity of *Cercospora* leaf spot on early sown cowpea. Dube *et al*. (2003) reported that soyabean planted early had high disease severity than late planted one. Gilbert and Tekauz (2000) in their study on wheat scab (also known as *Fusarium* head blight) caused by *Fusarium graminearum* reported that frequent rainfall, high humidity and heavy dew favoured the growth, survival and dissemination of the pathogen, hence the high incidence and severity of the disease. Marley (2004) reported that early sowing increased anthracnose severity in susceptible cultivars of sorghum which was attributed to longer exposure to high relative humidity.

However, Gurama *et al*. (1998) reported that scab severity was lower on early sown cowpea than on late sown crops.

The disease incidence and severity on the plants from seeds sown on the 19th of August, which is the second sowing date, were lower compared to the first sowing date. This is in agreement with the study conducted by Mbong *et al.* (2010a) who reported that cowpea planted on August 12 for a period of three years had lower incidence and severity compared with those planted earlier. The variance in disease incidence and severity is indicative of the role of environmental conditions in disease development (Appendix II). According to Emechebe (1980), scab is more severe under wet conditions because the conidia are supposedly dispersed by rain splash, and that the wet conditions result in high relative humidity (Emechebe & Florini, 1997). Similarly, Edema *et al*. (1997) reported higher incidence and severity of scab on cowpea in Uganda during the wetter season (March to June) than drier season (September to November).

The late sown cowpea of August 29, 2016 showed no scab infections which could be attributed to a change in the environmental condition, thus not favouring the development of the organism. This is in agreement with Akande *et al*. (2012) who reported that there was no infection of *Cercospora* leaf spot and *Choanephora* pod rot on late sown cowpea. Shailbala and Pundhir (2006) in their study on late blight of potato also reported that disease severity was significantly lower when planting time was delayed. Subedi *et al*. (2007) in their three year study conducted in Ottawa, Canada reported that late planting of wheat (Mid-May to July) increased scab incidence and severity. Brennan *et al*. (2005) observed that sowing date can influence the incidence of *Fusarium* head blight by inducing temperature and moisture availability which was corroborated by Miedaner *et al*. (2008) who reported that manipulation of sowing date is one of the most important methods of controlling wheat scab. The use of sowing dates has been observed to reduce or delay the development of anthracnose disease (Gwary *et al*., 2005; Rekha and Singh, 2015).

The effect of scab severity on the varieties showed that the varieties differed in their reaction to scab infection. This may be due to differences in the genetic makeup (Afutu *et al*., 2016). Nakawuka and Adipala (1997) reported that 86.7 % out of 75 cowpea lines screened against scab were susceptible. In this study, Ife Brown and SAMPEA 6 were most susceptible with infection recorded on all the aerial parts of the plant; this is in agreement with the study of Mbong *et al*. (2014) who reported susceptibility of these varieties to scab. Alabi (1994) and Akande (2007) reported that Ife Brown was highly susceptible to Brown blotch. Bosah (2013) reported that Ife Brown was highly susceptible to attack by microorganisms mostly fungi. Similarly, SAMPEA 8 was moderately susceptible to scab infection with all aerial parts affected. This is in agreement with Mbong *et al*. (2010a) who reported that SAMPEA 8 was moderately susceptible to scab. Sangoyomi and Alabi (2016) also reported susceptibility of SAMPEA 8 to cowpea leaf spot. The severity of scab on the susceptible varieties showed that the disease can be devastating under severe adverse conditions when susceptible varieties are planted. This agrees with Marley (2004) who reported increased severity of anthracnose disease on susceptible cultivar of sorghum.

TVx 3236 was the least affected of the varieties as the severity of scab was minimal on the aerial parts which is an indication that it is moderately resistant to scab. This agrees with Mbong *et al*. (2010a) who found that TVx 3236 was moderately affected by the scab disease. Konate and Ouedraogo (1988) reported that TVx 3236 which was resistant to scab in Nigeria was susceptible in Burkina Faso and it was suggested that it is due to variability in patho-type of the scab pathogen. Adebitan *et al*. (1992) reported that TVx 3236 was highly resistant to Brown blotch and anthracnose of cowpea.

SAMPEA 11, a variety considered to be resistant to scab disease (IAR Variety Descriptor, 2015) had a bout of the infection even though it was minimal. Chongo *et al.* (2001) reported that there is yet no cultivar available with complete resistance with respect to wheat scab which may also be likely with cowpea scab. Afutu (2017) reported that of the five improved varieties released in Uganda, only one variety is moderately resistance to scab disease. Little is known about the genetics of resistance to the disease (Tumwegamire *et al*., 1998). There is the likelihood that the resurgence of the disease could be due to the development of variability in patho-types of the fungus, changing weather patterns or a breakdown in the resistance (Hall and Van Sanford, 2003; Afutu, 2017). Iceduna *et al* (1994) worked on 80 lines of cowpea varieties at Uganda and reported that no line was completely free of scab infection.

The path coefficient analysis showed that the highest individual contribution of scab severity on yield of cowpea was on the pod and flower cushion. This agrees with Emenchebe (1980) who reported that the most destructive phase is on the flower axis causing flower and pod abortion or even preventing flower formation. The direct and indirect contribution of scab infected plant parts on yield showed negative and positive effects on seed weight which certainly influence yield. This is in line with Babaji *et al.,* (2006) and Mbong *et al.,* (2012) who reported that any factor that positively or negatively affect grain yield would have influence on yield.

The effects of sowing date on yield showed that cowpea sown on August 9, 2016 had the highest yield and yield components which could be attributed to minimal infection on the flower cushion and pod. This is in line with Elhag and Hussein (2014) who reported highest yield in early sown snap bean. Futuless *et al.* (2010) reported that cowpea sown on August 8 had significantly higher yield than late sown. Mbong *et al*. (2010a) reported that early sown SAMPEA 6 had higher yield than late sown. Rekha and Singh (2015) in their work on anthracnose of sorghum reported higher yield for early sown sorghum which was attributed to early access to soil nutrients, thus, favouring growth in spite of high severity of the disease. Sadeghi and Niyaki (2013) and Gaspar and Conley (2015) reported highest yield for early sown soyabean. Shailbala and Pundhir (2006) and Singh (2007) also reported that the higher yields from potato cultivars were achieved when early planting dates were used. However, Mbong *et al*. (2010a) reported low yield for TVx 3236 planted July 26; this was attributed to severity of scab infection. Mungo (1996) reported low yield of early sown cowpea which was attributed to scab infection. Asio *et al*. (2005) reported low yields of cowpea planted early in the season in Uganda. This was attributed to heavy rainfall favouring excessive vegetative growth, few pods and lower grain yields.

The cowpea sown on August 29, 2016 had low yield despite the non-appearance of the disease on the varieties; this could be as a result of abrupt cessation of rain during the period (Appendix II), which negatively affected both the vegetative and reproductive stages of the crop. This corroborated the study of Mirzaienasab and Mojaddam (2014) who reported that delay in planting with its attendant low rainfall appears to affect both vegetative and reproductive growth, consequently affecting the yield. Useni *et al*. (2014) in their work on the effects of planting date and spacing on growth and production of cowpea reported that late sowing leads to slower growth and lower yield. This report is similar to the study undertaken in Turkey by Togay *et al*., (2014) who reported that delayed sowing significantly reduced the yield of cowpea seed. Futuless *et al*. (2010) reported that late sowing of cowpea in Mubi affected the pod yield and consequently the total yield per hectare. Shahzad *et al.* (2003) reported that late sowing of wheat reduced yield and was attributed to the characteristics of the crop being adversely affected by the late planting; this study was supported by Shahbazi *et al*. (2016) who also reported low yield on late sown wheat despite the low level of scab disease. Salehi *et al*. (2006) reported that delay in sowing led to decrease in grain yield. Board *et al.* (1999), Egli and Bruening (2000) and Kantolic and Slafer (2001) reported decreased yield in late sown soyabeans. Mousavi *et al*. (2005) reported that delay in planting red bean resulted in low yield. However, Matikiti (2015) in the work carried out in Zimbabwe reported highest grain yield with late planting of black-eyed bean.

The varieties showed differences in their performance; this is in line with a study conducted to evaluate eight varieties of cowpea by Agbogidi and Egho (2012) which showed that significant differences existed among the varieties in their performance. The cultivar SAMPEA 11 considered resistant to scab, in spite of the infection had the highest yield. This is in agreement with Khajepoor (2000) who reported that the use of improved seeds increase crop yield. Similarly, Asio *et al*. (2005) observed higher grain yield in an improved variety in Uganda. SAMPEA 8, a susceptible variety had an appreciable yield in spite of the scab symptoms. This finding corresponds with that of Amadi (1998) who observed that the yield of cowpea was appreciable in spite of the various disease levels; this he attributed to the yield not been affected by the disease. Akande (2007) in a study conducted observed that although the cowpea variety IT84S-2246 was susceptible to *Cercospora* leaf spot and Brown blotch, it was still highly productive and he opined that the seed yield potential of the variety reduced the effect of the disease on the yield. In this study, the highly susceptible varieties, Ife Brown and SAMPEA 6 had more prominent scab symptoms including pod deformation and mummification (Plate IV and V) recorded on them thereby resulting in low yields which could be attributed to the disease since it affects all aboveground part of the variety. This is in agreement with earlier reports by Emechebe (1980), Iceduna, (1993), Gurama *et al*. 1998 and Mbong *et al.* (2016) who worked on scab of cowpea. TVx 3236, a moderately resistant variety had the lowest yield. This is in line with the study of Mbong *et al.* (2010a) who reported low yield for TVx 3236 and attributed it to other factors. An on-farm trial conducted by World Bank assisted Agricultural Development Projects in 1983 showed that the average yield for TVx 3236 was 1200 kg/ha (Singh, 1984). Based on this premise, it can be said that the variety, TVx 3236 was not affected by the disease; however, seed size could be a factor that account for the total seed weight per hectare.

The seed borne fungi, *Elsinoe phaseoli* had effect on the viability and vigour of the varieties but was more profound on the susceptible varieties, showing marked decrease in the germination percentage. The path coefficient analyses in this study showed that scab infection on the different plant parts had influence on the seed quality. This agrees with Ahmed and Ahmed (1994) who stated that disease plays an important role in reducing the quality of mustard seed.

Cowpea sown on August 9, 2016 recorded the highest disease incidence and severity with reduction in germination percentage, high electrolyte leakage and low vigour which are an indication of loss of physiological quality as a result of being infected with *Elsinoe phaseoli*. This agrees with Pradhan *et al*. (2017) that fungi associated with crop seed play an important role in seed deterioration. Abdelmoen and Ramsy (2000) proposed that the higher the disease occurrence, the lower the germination percentage and vigour. Nightingale *et al*., (1999) also reported that physiological changes caused by fungal infections could lead to considerable reduction in seed quality. Malik and Jyoti (2013) reported that the primary reason for loss of viability and vigour is as a result of membrane deterioration which is caused by the infiltration of the seed-borne fungi leading to seed deterioration. However, membrane deterioration was not conducted in this study.

The laboratory test results for cowpea planted August 29, 2016 gave a better germination percentage and high seedling vigour despite the high electrolyte leakage as shown in the electrical conductivity test which could be as a result of some factors. Vieira *et al.* (2002) attributed this to initial seed moisture content been low thereby causing structural disorganization of the cellular membranes. Also, the ability of the seed to restore its cell membrane integrity quickly during water uptake at the onset of germination due to its genetic makeup was another reason given for the high electrolyte leakage (Carvalho *et al.,* 2009). Therefore, a higher electrical conductivity value might not necessarily translate to low seed vigour (Bewley and Black, 1994). A higher physiological quality (germination and vigour) indicates greater probability of having good seed performance under a wider range of environmental conditions (Vieira *et al*., 1994; Egli & TeKrony, 1996; Marcos-Filho, 1999). This agrees with Akande *et al.* (2012) who reported that late sown cowpea produce better seed quality, as measured in terms of quality tests carried out. Sangakkara (1998) reported that the establishment of late sown cowpea produced better quality seeds. Alabi (1994) in her work on Brown blotch reported better seed quality on late sown cowpea.

The varieties SAMPEA 6, Ife Brown and SAMPEA 8 which were susceptible to scab had the lowest germination percentage (viability) which could be attributed to the disease. This is supported by Lee-Stadelmann *et al*. (1991) who reported that fungi infestations cause damage to the seeds. Begum *et al*. (2008) reported reduced germination percentage in soybean seeds inoculated with *Colletotrichum truncatum*. Basavaraju *et al*. (2004) reported low germination percentage in sunflower infected with *Plasmopara halstedii*. Haider and Ahmed (2014) reported that poor seed quality such as low viability affected the yield of mungbean. Abdelmoen and Ramsy (2000) reported that low viability/germination and yield reduction are as a result of the activities of the pathogen.

The electrical conductivity test result for the varieties, SAMPEA 6, SAMPEA 8 and Ife Brown indicated high electrolyte leakage. This agrees with Lee-Stadelmann *et al*. (1991) who attributed inducement of electrolyte leakage to fungi infestation. In the study, negative and significant correlation observed between electrical conductivity and germination tests is an indication that the high electrolyte leakage led to reduced germination. This in line with Chhetri (2009) who in his study on rice (*Oryza sativa,* L.) stated that low viability and vigour of seeds had high amount of electrolyte leakage. Begum *et al*. (2008) reported high electrolyte leakage in seeds of soyabean inoculated with *Colletotrichum truncatum*. Malik and Jyoti (2013) reported that high electrolyte leakage is associated with a decline in seed germination and vigour. In a study conducted by Hampton *et al*. (1992), decline in germination and vigour of seeds of soybean were reported to be directly proportional to rise in solutes leakage from the seeds. Galli *et al*. (2007) reported that seed-borne pathogens reduce the physiological potential of soybean seed. Low germination percentage was recorded after the accelerated ageing test with weak seedlings emergence which is an indication of the inability of these susceptible varieties to be viable under prolonged storage and stressful field environmental conditions. This is in line with the study of Hussein *et al*. (2011) who reported loss of seed viability and vigour in sunflower after being subjected to the accelerating ageing test.

The varieties SAMPEA 11 and TVx 3236 had high physiological viability and vigour, in spite of high electrolyte leakage. This could be attributed to their genetic makeup. This agrees with Copeland and McDonald (2001) who reported that the genetic factor of the seed can influence the seed vigour and viability. Baalbaki *et al* (2009) opined that high vigour seed tolerate stressful conditions better than low vigour seeds, thereby producing higher percentage of normal seedlings. Akande *et al*. (2012) in the study conducted on effect of *Cercospora* leaf spot and *Choanephora* pod rot on seed quality of cowpea reported that the germination percentage and vigour of the local variety Ex-erusu were significantly higher than the other varieties used. They attributed this to the fact that it is a well-adapted variety; this can be used to explain the high physiological quality of SAMPEA 11 and TVx 3236 which are varieties adapted to this environment.

CHAPTER SIX

6.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

6.1 Summary

The effect of sowing date on the incidence and severity of scab were assessed on five cowpea varieties, SAMPEA 6, SAMPEA 8, SAMPEA 11, TVx 3236 and Ife brown using three sowing dates at 10 days intervals, August 9, 19 and 29, 2016. The cowpea varieties sown on the first sowing date had significantly higher incidence and severity of scab on the different plant parts than the second sowing date while there was no record of infection for those sown at the third sowing date. There was a variation in the reaction of the varieties to scab infection with Ife brown and SAMPEA 6 being highly susceptible, SAMPEA 8 was susceptible, TVx 3236 was moderately resistant while SAMPEA 11 which is regarded as a resistant cultivar to scab had low incidence and severity. The first sowing date had significantly higher seed yield compared to the other two sowing dates which were not different from each other. For the variety, SAMPEA 11 had the highest seed yield. The investigations on quality of harvested seeds showed that there was reduced germination of the varieties, SAMPEA 6, SAMPEA 8 and Ife brown while SAMPEA 11 and Tvx 3236 had a good germination indicating high vigour and viability.

6.2 Conclusion

The following conclusions can be made from this study:

(i) Cowpea scab induced by *Elsinoe phaseoli* affected all above ground parts of the plant. The variety, SAMPEA 6 had highest scab severity on leaves, stems, flower cushions and pod, being 25.11 %, 31.44 %, 19.56 % and 18.11 %, respectively while SAMPEA 8 had highest on peduncles scab, 18.33 %. Sowing dates influenced both the incidence and severity of scab with highest observed on cowpea sown on first sowing date, August 9 while there was no scab infection for cowpea sown on third sowing date, August 29, 2016. The highest seed yield of 1,792.60 kg/ha was recorded for crops sown on the August 9, 2016 while those sown on August 19 had the least, 1,192.60 kg/ha.

(ii) The varieties, SAMPEA 6, SAMPEA 8 and Ife Brown were susceptible to scab disease while TVx 3236 and SAMPEA 11 were moderately resistant.

(iii) The seed borne fungi, *Elsinoe phaseoli,* had effects on viability and vigour of the varieties. Germination was reduced by 73 % and vigour by 92.5 %, respectively.

(iv) Pod yield was highest in SAMPEA 6 and lowest in TVx 3236

6.3 Recommendations

Based on the findings of this study, it is recommended that:

(i) resistant varieties should be sown by farmers in scab-endemic areas. These lines could be used by breeders in the development of scab-resistant cowpea varieties.

(ii) the combination of moderately resistant varieties and sowing dates had a profound effect on the disease development and yield. Therefore, SAMPEA 11 and TVx 3236 sown at 2nd week of August can form part of an integral part of integrated disease management (IDM) strategy.

(iii) since scab disease affect cowpea seed quality, seeds from infected plants should not be used for sowing in subsequent seasons as this may affect overall yield.

(iv) Further studies should be conducted to screen more cowpea germplasm for resistance to scab disease in order to make more moderately resistant varieties available for farmer’s use as this is a cheap way of management.

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APPENDICES

Appendix I: ANOVA Tables

I.1 Incidence of scab on leaf of cowpea at 4 WAS

Source	DF	Sum of Square	Mean Square	F value	Pr > F
Model	16	10746.66667	671.66667	6.59	<.0001
Error	28	2853.33333	101.90476		
Corrected Total	44	13600.00000			

I.2 Incidence of scab on leaf of cowpea at 8 WAS

Source	DF	Sum of Square	Mean Square	F value	Pr > F
Model	16	33053.33333	2065.83333	22.02	<.0001
Error	28	2626.66667	93.80952		
Corrected Total	44	35680.00000			

I.3 Incidence of scab on leaf of cowpea at 12 WAS

Source	DF	Sum of Square	Mean Square	F value	Pr > F
Model	16	47208.88889	2950.55556	26.52	<.0001
Error	28	3115.55556	111.26984		
Corrected Total	44	50324.44444			

I.4 Incidence of scab on stem of cowpea at 4 WAS

Source	DF	Sum of Square	Mean Square	F value	Pr > F
Model	16	12848.88889	803.05556	8.40	<.0001
Error	28	2675.55556	95.55556		
Corrected Total	44	15524.44444			

I.5 Incidence of scab on stem of cowpea at 8 WAS

Source	DF	Sum of Square	Mean Square	F value	Pr > F
Model	16	44746.66667	2796.66667	23.21	<.0001
Error	28	3373.33333	120.47619		
Corrected Total	44	48120.00000			

I.6 Incidence of scab on stem of cowpea at 12 WAS

Source	DF	Sum of Square	Mean Square	F value	Pr > F
Model	16	63120.00000	3945.00000	40.02	<.0001
Error	28	2760.00000	98.57143		
Corrected Total	44	65880.00000			

I.7 Incidence of scab on peduncle of cowpea at 4 WAS

Source	DF	Sum of Square	Mean Square	F value	Pr > F
Model	16	1173.333333	73.333333	2.75	<.0001
Error	28	746.666667	26.666667		
Corrected Total	44	1920.000000			

I.8 Incidence of scab on peduncle of cowpea at 8 WAS

Source	DF	Sum of Square	Mean Square	F value	Pr > F
Model	16	15373.33333	960.83333	9.79	<.0001
Error	28	2746.66667	98.09524		
Corrected Total	44	18120.00000			

I.9 Incidence of scab on peduncle of cowpea at 12 WAS

Source	DF	Sum of Square	Mean Square	F value	Pr > F
Model	16	41142.22222	2571.38889	16.18	<.0001
Error	28	4448.88889	158.88889		
Corrected Total	44	45591.11111			

I.10 Incidence of scab on flower cushion of cowpea at 5 WAS

Source	DF	Sum of Square	Mean Square	F value	Pr > F
Model	16	568.888889	35.555556	1.00	0.4838
Error	28	995.555556	35.555556		
Corrected Total	44	1564.444444			

I.11 Incidence of scab on flower cushion of cowpea at 8 WAS

Source	DF	Sum of Square	Mean Square	F value	Pr > F
Model	16	4613.333333	288.333333	2.07	0.0449
Error	28	3906.666667	139.523810		
Corrected Total	44	8520.000000			

I.12 Incidence of scab on flower cushion of cowpea at 12 WAS

Source	DF	Sum of Square	Mean Square	F value	Pr > F
Model	16	11680.00000	730.00000	3.34	0.0026
Error	28	6120.00000	218.57143		
Corrected Total	44	17800.00000			

I.13 Incidence of scab on pod of cowpea at 8 WAS

Source	DF	Sum of Square	Mean Square	F value	Pr > F
Model	16	386.6666667	24.1666667	1.27	0.2821
Error	28	533.3333333	19.0476190		
Corrected Total	44	920.0000000			

I.14 Incidence of scab on pod of cowpea at 10 WAS

Source	DF	Sum of Square	Mean Square	F value	Pr > F
Model	16	2235.555556	139.722222	3.93	0.0008
Error	28	995.555556	35.555556		
Corrected Total	44	3231.111111			

I.15 Incidence of scab on pod of cowpea at 12 WAS

Source	DF	Sum of Square	Mean Square	F value	Pr > F
Model	16	3533.333333	220.833333	4.59	0.0002
Error	28	1346.666667	48.095238		
Corrected Total	44	4880.000000			

I.16 Severity of scab on leaf of cowpea at 4 WAS

Source	DF	Sum of Square	Mean Square	F value	Pr > F
Model	16	222.4888889	13.9055556	8.14	<.0001
Error	28	47.8222222	1.7079365		
Corrected Total	44	270.3111111			

I.17 Severity of scab on leaf of cowpea at 8 WAS

Source	DF	Sum of Square	Mean Square	F value	Pr > F
Model	16	1617.955556	101.122222	9.24	<.0001
Error	28	306.355556	10.941270		
Corrected Total	44	1924.311111			

I.18 Severity of scab on leaf of cowpea at 12 WAS

Source	DF	Sum of Square	Mean Square	F value	Pr > F
Model	16	4769.333333	298.083333	11.09	<.0001
Error	28	752.666667	6.880952		
Corrected Total	44	5522.000000			

I.19 Severity of scab on stem of cowpea at 4 WAS

Source	DF	Sum of Square	Mean Square	F value	Pr > F
Model	16	288.4888889	18.0305556	9.50	<.0001
Error	28	53.1555556	1.8984127		
Corrected Total	44	341.6444444			

I.20 Severity of scab on stem of cowpea at 8 WAS

Source	DF	Sum of Square	Mean Square	F value	Pr > F
Model	16	3731.155556	233.197222	13.22	<.0001
Error	28	494.088889	17.646032		
Corrected Total	44	4225.244444			

I.21 Severity of scab on stem of cowpea at 12 WAS

Source	DF	Sum of Square	Mean Square	F value	Pr > F
Model	16	12461.06667	778.81667	17.38	<.0001
Error	28	1254.93333	44.81905		
Corrected Total	44	13716.00000			

I.22 Severity of scab on peduncle of cowpea at 4 WAS

Source	DF	Sum of Square	Mean Square	F value	Pr > F
Model	16	1163.733333	72.733333	272.75	<.0001
Error	28	7.466667	0.266667		
Corrected Total	44	1171.200000			

I.23 Severity of scab on peduncle of cowpea at 8 WAS

Source	DF	Sum of Square	Mean Square	F value	Pr > F
Model	16	411.0666667	25.6916667	8.27	<.0001
Error	28	86.9333333	3.1047619		
Corrected Total	44	498.0000000			

I.24 Severity of scab on flower cushion of cowpea at 5 WAS

Source	DF	Sum of Square	Mean Square	F value	Pr > F
Model	16	1133.688889	70.855556	199.28	<.0001
Error	28	9.955556	0.355556		
Corrected Total	44	1143.644444			

I.25 Severity of scab on flower cushion of cowpea at 8 WAS

Source	DF	Sum of Square	Mean Square	F value	Pr > F
Model	16	97.6000000	6.1000000	2.12	0.0392
Error	28	80.4000000	2.8714286		
Corrected Total	44	178.0000000			

I.26 Severity of scab on flower cushion of cowpea at 12 WAS

Source	DF	Sum of Square	Mean Square	F value	Pr > F
Model	16	1972.622222	123.288889	6.24	<.0001
Error	28	553.022222	19.750794		
Corrected Total	44	2525.644444			

I.27 Severity of scab on pod of cowpea at 8 WAS

Source	DF	Sum of Square	Mean Square	F value	Pr > F
Model	16	1049.466667	65.591667	10.06	<.0001
Error	28	182.533333	6.519048		
Corrected Total	44	1232.000000			

I.28 Severity of scab on pod of cowpea at 10 WAS

Source	DF	Sum of Square	Mean Square	F value	Pr > F
Model	16	442.6222222	27.6638889	3.92	0.0008
Error	28	197.6888889	7.0603175		
Corrected Total	44	640.3111111			

I.29 Severity of scab on pod of cowpea at 12 WAS

Source	DF	Sum of Square	Mean Square	F value	Pr > F
Model	16	1054.355556	65.897222	4.14	0.0005
Error	28	445.955556	15.926984		
Corrected Total	44	1500.311111			

I.30 Seed weight (kg/Ha)

Source	DF	Sum of Square	Mean Square	F value	Pr > F
Model	16	4583817.224	286488.576	2.55	0.0145
Error	28	3141827.495	112208.125		
Corrected Total	44	7725644.719			

I.31 Pod weight (kg/Ha)

Source	DF	Sum of Square	Mean Square	F value	Pr > F
Model	16	15494095.33	968380.96	5.32	<.0001
Error	28	5094112.52	181932.59		
Corrected Total	44	20588207.85			

I.32 Stand count on the field

Source	DF	Sum of Square	Mean Square	F value	Pr > F
Model	16	1433.155556	89.572222	5.36	<.0001
Error	28	467.822222	16.707937		
Corrected Total	44	1900.977778			

I.33 Germination test

Source	DF	Sum of Square	Mean Square	F value	Pr > F
Model	16	13765.60000	860.35000	27.64	<.0001
Error	28	871.60000	31.12857		
Corrected Total	44	14637.20000			

I.34 Electrical conductivity test

Source	DF	Sum of Square	Mean Square	F value	Pr > F
Model	16	4643.239102	290.202444	1.99	0.0542
Error	28	4089.385476	146.049481		
Corrected Total	44	8732.624578			

I.35 Accelerated aging test

Source	DF	Sum of Square	Mean Square	F value	Pr > F
Model	16	6700.355556	418.772222	16.86	<.0001
Error	28	695.422222	24.836508		
Corrected Total	44	7395.777778			

Appendix II: 2016 Weather Report

II.1 Average weather report for first sowing date

	Rainfall (mm)/day	Relative Humidity (%)	Temperature (°C)
Aug. 9 to Sept. 8	13.63	70.6	23.5
Sept.9 to Oct. 8	5.33	46.1	15.9
Oct. 9 to Nov. 8		44.3	25.8

II.2 Average weather report for second sowing date

	Rainfall (mm)/day	Relative Humidity (%)	Temperature (°C)
Aug. 19 to Sept. 18	13.39	57.7	19.2
Sept. 19 to Oct. 18	1.56	55.6	20.6
Oct. 19 to Nov. 28	nil	29.9	24.7

II.3 Average weather report for third sowing date

	Rainfall (mm)/day	Relative Humidity (%)	Temperature (°C)
Aug. 29 to Sept. 28	12.05	43.5	14.6
Sept. 29 to Oct. 28	nil	56.1	24.5
Oct 29 to Nov. 28	nil	23.3	23.5

Source: Meterology Unit, IAR, 2016