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Effect of Plant Density on Rust Severity and Yield of Soybean

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***Abstract* – Limited research studies have been conducted on the effects of cultural practices in the management of soybean rust. The present study investigates the effect plant density on the severity of rust pathogen and its concomitant effect on the yield of soybean under natural infection conditions. The experiment was laid in a Randomized Complete Block Design (RCBD) with three replicates. The treatments consist of soybean seeds sown at the rate of one plant per stand (T1), two plants per stand (T2), three plants per stand (T3) and four plants per stand (4). The parameters assessed include rust incidence and severity, number of pods per plant, number of seeds per pod, 100 seed weight and total seed yield. Although, rust severity was higher in T4 than the other treatments, the disease incidence was observed to be lowest in T4. At 11 WAP, there was no significant difference in rust severities among soybean plants in T1, T2 and T3 (5.4, 5.2 and 5.7, respectively). A significantly ($P \leq 0.05$) higher number of pods (39) were observed on T4 plots. T1 and T2 produced pod numbers that were not significantly different (19 and 22 pods per plant). There was no significant difference in the number of seeds produced per pod among the treatments. T4 had a significantly ($P \leq 0.05$) higher seed yield (1153kgha^{-1}) among all the treatments, followed by seed yield in T3 plots which was significantly higher than T2 and T1. There was no significant difference in seed yields observed in T1 and T2 plots. The current study shows adjustment of planting density as one of the effective approaches of mitigating the impact of soybean rust to maximize yield potential. Findings from this research work reveal that farmers may use higher seeding rates in soybean-prevalent or endemic areas in order to compensate for yield loss that may arise from rust severity.**

***Keywords* – Rust, Phakopsora Pachyrhizi, Soybean, Plant Density, Disease Severity, Yield.**

I. Introduction

Soybean (*Glycine max* L.) has become one of the most important and versatile leguminous crops utilized as food and feed source in many developing countries of the world Tukamuhabwa and Maphosa [1]. The legume is richer in protein than any of the common vegetables or animal food sources found in Nigeria [2]. It has excellent protein content (40%) of good nutritional quality, high oil content (20%), as well as numerous beneficial nutrients and bioactive factors, all of which combine to make soybean a highly desirable crop with the potential to improve the diets of millions of people in the developing countries [3]. It is therefore crucial that any constraint or threat to soybean production be adequately addressed to expand and/or sustain soybean industry in Africa as well as other developing nations of the world [4].

Among the developing regions of the world, the continent of South America is the leading producer of soybean in terms of area and tonnage, while Africa is the least [5]. The largest soybean-producing countries in Africa are Nigeria, South Africa, Uganda, Malawi and Zimbabwe. Nigeria is the leading producer of soybean in Africa with an annual production figure of 480,000t/ha 2010 [6]. This production estimate, however, accounts for only 0.25% of the world annual output of 173 million tons [6].

Generally, the average grain yield of soybean is low in tropical Africa, with less than 1 ton/ha [7]. Weeds, insect pests and diseases constitute the major biotic constraint to optimum soybean production. Diseases are, however, the most important threat [8]. Common diseases of soybean include rust, red leaf blotch, frog-eye leaf spot, bacterial pustule, bacterial blight, *Sclerotinia* stem rot, cyst, sudden death syndrome and soybean mosaic virus.

Rust, caused by the fungus, *Phakopsora pachyrhizi* is the most devastating foliar disease of soybean worldwide, accounting for yield losses of 13-80% [9]. In more severe cases, rust can cause yield losses of up to 100%, particularly where control measure is not embarked upon [10, 11, 12, 13).

Soybean rust affects the organs of photosynthesis and causes premature defoliation, resulting in significant reduction in seed filling potential, number of pods per plant, pod weight and grain yield, particularly in the susceptible varieties (14, 15). Disease control strategies for soybean rust are limited owing to variability of the fungus that complicates most management approaches [1]. Fungicide application is currently the major effective measure recommended for managing the disease [16]. However, many fungicides have lost potency and efficacy owing to the development of resistance by rust pathogens [17]. Furthermore, the prohibitive cost, phytotoxicity, deleterious effects on agricultural land, water and soil as well as the associated health problems on man have necessitated the need to search for alternative control measures that are cheap, environment-friendly, ecologically sound and medically safe [18].

Adoption or modification of some cultural practices has been recognized as a sound alternative to the use of synthetic chemicals in plant disease control. Certain cultural practices have been demonstrated to influence the incidence and severity of many plant pathogens [19]. Limited research studies have been conducted on the effects of cultural practices in the management of soybean rust [20]. Cultural practices that reduce crop exposure to favourable growth conditions are likely to influence rust development. The present study therefore investigates the effect plant density on the severity of rust pathogen and its concomitant effect on the yield of soybean under natural infection conditions.

II. Materials and Methods

Site Description

The research work was carried out at the Teaching and Research Farm of Landmark University, Omu-Aran, Kwara State, Nigeria. The site lies between latitude 8°8' N and longitude 5°6' E of the equator. Annual rainfall ranges between 600 and 1,500 mm with a distinct dry season from December to March [21]. The mean annual temperature varies from 28°C to 34°C. The humidity ranges between 50% in the dry season to about 85% during wet season.

History of the Experimental Field

The land used for this experiment was previously cropped with soybeans for two consecutive periods (June to September, 2013 and June to September, 2014). During these periods, rust of soybeans was observed on the field.

Source of Seeds

TGx1448-2E seeds of soybean used in this research work were obtained from the Teaching and Research Farm of Landmark University, Omu-Aran. The cultivar was selected for the trial based on its popularity in this agro-ecological zone as well as its drought tolerance and moderate resistance to rust pathogen.

Experimental Design and Treatment Application

The field used for the experiment was cleared and harrowed. A total of 12 plots were used for the trial, with each plot measuring 2m by 3m. Plots were separated from one another by 0.5m alleys. The experiment was laid in a Randomized Complete Block Design (RCBD) with three replicates. The treatments consist of soybean seeds sown at the rate of one plant per stand (T1), two plants per stand (T2), three plants per stand (T3) and four plants per stand (4).

Data Collection

Symptom Observation and Disease Rating

The plants were observed for rust symptoms under natural infection conditions. Disease rating which was carried out beginning from seven weeks after planting was based on visible macroscopic symptoms characteristic of soybean rust; small gray lesions that changed to red-brown polygonal pustules (2-5 mm^2) on the abaxial surface [22].

For rust incidence, all the plants in each treatment were examined and scored, while for severity, 20 plants were randomly selected from the three inner rows of each plot. The first three trifoliate leaves, designated as T-1, T-2 and T-3 (T-1 denoting the oldest trifoliate leaf immediately above the primary leaves) were scored visually using Srivastava and Gupta [23] modified scale of 0-9, where,

0= no lesions/spots
1= 1% leaf area covered with pustules
3= 1.1-10% leaf area covered with pustules
5= 10.1-25% leaf area covered with pustules
7= 25.1-50% leaf area covered with pustules, and
9= greater than 50% leaf area covered with pustules

Harvesting and Yield Components/Yield Estimation

At maturity, all pods were harvested manually from the three middle rows of each plot. The number of pods per plant was obtained by randomly selecting 20 plants from each plot and calculating the average. Forty pods were randomly selected from each treatment to determine the number of seeds per pod. Total seeds harvested and 100 seeds (counted from total yield) were weighed separately to determine the total yield and 100 seed weight, respectively.

Statistical Analysis

The data obtained were subjected to analysis of variance (ANOVA) and the means were separated using Duncan Multiple Range Test (DMRT) at 5% probability level.

III. Results

3.1 *Meteorological Data*

The meteorological data i.e. rainfall, relative humidity, solar radiation and temperature of the experimental field is presented in Table 1.

3.2 *Disease Incidence*

Rust incidence was observed to increase with plant age (Table 2). At 7 WAP, T1 had the highest rust incidence (13.3%) which was significantly (P≤0.05) higher than all other treatments. This was followed by T2 which was significantly higher than T3 and T4. There was no significant difference in rust incidence observed on T3 and T4 plants at 7 WAP (10.7 and 10.2%, respectively).

At 8 and 9 WAP, T1 had the highest disease incidence which was not significantly (P≤0.05) different from T2. The least rust incidence was noticed in T4 plants at 8 and 9 WAP. At 10 WAP, T1 had a significantly (P≤0.05) higher rust incidence than all other treatments. The least rust incidence was observed in T4 plants at 10 WAP (16.3%). At 11 WAP, T1 had significantly (P≤0.05) higher rust incidence (46.7%) than all other treatments. This was followed by T2 (31.4%) which was significantly higher than T3. The lowest disease incidence was noticed in T4 plants (19.3%).

3.3 *Disease Severity*

At 7 WAP, there was no significant difference in rust severity among T1, T2 and T3 plants (Table 3). At 8 WAP, there was no significant difference (P≤0.05) in rust severities observed on soybean plants in T2 and T3 plants (1.7 and 1.8 respectively). At 9 WAP, T1 and T2 had statistically similar rust severities. At 10 WAP, there was no significant difference in disease severities between T2 and T3 while a significantly lower rust severity was observed on soybean plants in T1 (4.1). At 11 WAP, there was no significant (P≤0.05) difference in rust severities among soybean plants in T1, T2 and T3 (5.4, 5.2 and 5.7, respectively).

3.4 *Number of Pods Per Plant*

A significantly (P≤0.05) higher number of pods (39) were observed on T4 plots (Table 4). T1 and T2 produced pod numbers that were not significantly different (19 and 22 pods per plant, respectively).

3.5 *Number of Seeds Per Pod*

There was no significant (P≤0.05) difference in the number of seeds produced per pod among the treatments (Table 5).

3.6 *100 Seed Weight*

T1 had significantly (P≤0.05) higher 100 seed-weight than all other treatments (Table 6). No significant difference in 100 seed weight was observed among T2, T3 and T4 plants.

3.7 *Yield*

T4 had a significantly (P≤0.05) higher seed yield (1153kgha^{-1}) among all the treatments (Table 7). This was followed by seed yield in T3 plots which was significantly higher than T2 and T1. There was no significant difference in seed yields observed in T1 and T2 plots.

3.8 *Hosts of Soybean Rust Pathogen Found on Adjacent Fields*

The primary and alternative hosts of soybean rust pathogen are presented in Table 8.

IV. Discussion

Plant density is a cultural management practice for some plant diseases [24]. Practices such as adjustment of row spacing and plant density have been reported to influence disease development. The current study examined the effect of plant density on the severity of soybean rust and its concomitant effect on yield. Higher rust severities were observed in soybeans sown at higher densities. The higher disease severity recorded with higher sowing rates is in agreement with the findings of Pande and Rao [25] that reported higher severity of leaf spot and rust of groundnut at higher plant densities.

Findings from this study show that adjustment of production practices such as sowing rates could help maximize yield potential. Adipala [26] also observed a positive correlation between disease severity and yield in maize infected with northern leaf blight disease. The higher grain yields recorded in this trial at higher plant densities corroborates the observation of Vanderpuye [27], who reported that increasing plant population density generally increase intercepted light, biomass and cumulative intercepted radiation on each sampling day after seeding, resulting in a general increase in seed yield.

Phakopsora pachyrhizi is an obligate parasite, with the primary inoculum being infected soybean plants or other live hosts that harbour the spores in their uredinial stage [28]. Jarvie [22] reported epidemics of soybean rust from low concentration of windborne urediniospores that survived the winter in alternative hosts of *P. pachyrhizi*. The fungus has a wild host range, covering over 95 species in more than 42 genera in the family Fabaceae [9]. Included in the list are several wild and edible legumes that are widely grown or prevalent throughout Sub-Saharan Africa. These could potentially serve as pathogen reservoirs, and thus, sustain the pathogen within the environment [4]. The several susceptible hosts of soybean rust pathogen observed on adjacent fields might have harboured the inoculum spores that entered the experimental field via wind borne to initiate rust infection. It could therefore be inferred that initial infections started from a low concentration of windborne urediniospores.

Asian soybean rust (SBR) develops quickly where environmental conditions are favourable. Frequent rains, long dew periods and temperatures ranging from 15°C to 29°C appear to be optimal for SBR development [29]. There is a paucity of information on the effect of environmental and meteorological conditions affecting rust pathogen in the field when compared to the available knowledge from growth chamber and greenhouse studies [28]. However, research has shown that epidemic components, environmental conditions and meteorological factors play significant roles in SBR epidemiology [30,31]. Meteorological factors affect the host and pathogen directly or indirectly, which results in complex interactions.

Climate is extremely important among the factors that influence the epidemiology of ASR [32]. Climatic factors affect the different stages of the disease cycle, thereby influencing the rate of progress and severity of the epidemics. The main climatic variables determining the occurrence of ASR are leaf wetness duration, average temperature during the wet period and relative humidity [33]. These variables influence disease progress by directly affecting the infection process of *P. pachyrhizi* [34].

In soybean fields, rainfall seems to be the most important factor that influences the severity of rust [20]. Rainfall-related variables accounted for most of the variation in the severity of ASR epidemics [35]. The high correlation between rainfall and disease severity can be explained by urediniospores of *P. pachyrhizi* released by raindrops, either through the effect of their splash or by the impact that they have on the leaves. Therefore, the high rainfall experienced in the months of September and October in the present study (Table 1) might have accounted for the observed rust severity at later growth stages of the crop. Del Ponte [35] reported that cumulative rainfall in the period after initial rust detection was positively correlated with disease severity, which probably accounted for the similarity in the rainfall and soybean rust distribution patterns.

Uredospores of *P. pachyrhizi* germinate at all temperatures within the range of 8 to 30ºC, with 15 to 25ºC being the optimum [36]. The temperature of 26.4-29.8 ºC recorded during the experimental period is within the range favourable for rust development. The number of pustules per lesion, as well as lesion size has been demonstrated to increase with increasing leaf wetness between 85 and 95% relative humidity [37]. In this study, the relative humidity in the months of September (91.6%), October (90.4%) and November (82.6%) concurs with the range considered suitable for rust disease development.

V. Conclusion

The current study shows adjustment of planting density as one of the effective approaches of mitigating the impact of soybean rust to maximize yield potential. Findings from this research work reveal that farmers may use higher seeding rates in soybean-prevalent or endemic areas in order to compensate for yield loss that may arise from rust severity.

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Table 1: Meterological data of Landmark University, Omu-Aran, during the experimental period

Month	Rainfall (mm)	Relative humidity (%)	Solar radiation	Temperature (°C)
September	251.7	91.6	173.6	26.4
October	300.0	90.4	184.3	26.3
November	94.7	82.6	202.2	27.8
December	0	60.0	206.1	29.0
January	64.3	46.5	201.2	28.0
February	27.4	69.8	212.7	29.8

*Values represent monthly average

Table 2: Effect of plant density on incidence of soybean rust (%)

Treatment	7 WAP	8 WAP	9 WAP	10 WAP	11 WAP
T1	13.3a	18.7a	24.2a	35.6a	46.7 a
T2	12.1b	17.6a	23.5a	19.5b	31.4b
T3	10.7c	14.3b	18.7b	20.3b	25.9c
T4	10.2c	11.7c	14.3c	16.3c	19.3d

Values followed by similar letters under the same column are not significantly different at P≤0.05 according to Duncan's multiple range test (DMRT); T1, T2, T3, T4 represents 1, 2, 3, 4 soybean plants per stand; WAP= Weeks after planting
*Values are means of three replicates

Table 3: Effect of plant density on soybean rust severity

Treatment	7 WAP	8 WAP	9 WAP	10 WAP	11 WAP
T1	1.2b	2.3b	3.6b	4.1c	5.4b
T2	1.5b	1.7c	3.5b	4.7b	5.2b
T3	1.3b	1.8c	2.4c	5.1b	5.7b
T4	2.2a	2.6a	4.0a	6.0a	6.6a

Values followed by similar letters under the same column are not significantly different at P≤0.05 according to Duncan's multiple range test (DMRT); T1, T2, T3, T4 represents 1, 2, 3, 4 soybean plants per stand; WAP= Weeks after planting
*Values are means of three replicates

Table 4: Effect of soybean rust on number of pods per plant

Treatment	Number of pods
T1	19c
T2	22c
T3	30b
T4	39a

Values followed by similar letters under the same column are not significantly different at P≤0.05 according to Duncan's multiple range test (DMRT); T1, T2, T3, T4 represents 1, 2, 3, 4 soybean plants per stand; WAP= Weeks after planting
*Values are means of three replicates

Table 5: Effect of soybean rust on number of seeds produced per pod

Treatment	Number of seeds/pod
T1	2.6a
T2	2.5a
T3	2.4a
T4	2. 4a

Values followed by similar letters under the same column are not significantly different at P≤0.05 according to Duncan's multiple range test (DMRT); T1, T2, T3, T4 represents 1, 2, 3, 4 soybean plants per stand; WAP= Weeks after planting
*Values are means of three replicates

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Table 6: Effect of soybean rust on 100 seed weight (g)

Treatment	100 seed weight (g)
T1	13.4a
T2	12.2b
T3	12.1b
T4	12.1b

T1, T2, T3, T4 represents 1, 2, 3, 4 soybean plants per stand
Values are means of three replicates
Means in a column followed by the same alphabet are not significantly different according to Duncan's Multiple Range Test (P≤0.05)

Table 7: Effect of soybean rust on total seed yield (kgha^{-1})

Treatment	Yield (kgha^{-1})
T1	869c
T2	878c
T3	1026b
T4	1153a

Values followed by similar letters under the same column are not significantly different at P≤0.05 according to Duncan's multiple range test (DMRT); T1, T2, T3, T4 represents 1, 2, 3, 4 soybean plants per stand; WAP= Weeks after planting
*Values are means of three replicates

Table 8: Hosts of *Phakopsora pachyrhizi* observed on fields adjacent to experimental site

Scientific name	Common name	Host status
Pachyrhizus erosus	Yam bean	++
Pueraria lobata	Kudzu	++
Vigna unguiculata	Cowpea	++
Delonix regia	Flamboyant	+
Lablab purpureus	Hyacinth bean	+
Phaseolus vulgaris	Kidney bean	+
Calapogonium mucunoides	Calapo	+

++ - Primary host
+ - Alternative host