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Efficacies and profitability of different fungicides and spray regimes for control of soybean rust(*Phakopsora pachyrhizi* Syd.) in Uganda

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Abstract

Three fungicides: Dithane- M45 (contact wettable powder), Saprol and Folicur (both systemic), and three spray regimes, weekly, 2-weekly, and 3-weekly sprays from disease onset to full seed formation, were evaluated against soybean rust incited by *Phakopsora pachyrhizi* Syd. These corresponded to 5, 3, and 2 sprays, respectively. Nam 2 a highly susceptible variety was used in the study. The unprotected soybean had significantly higher rust severities (> 75%) and lower yields (968 kg/ha) as compared to the rust-protected soybean, with rust severities (< 70%) and yields (> 1000 kg/ha). Highest yield increase with Dithane, Saprol, and Folicur of 26.9, 33.3 and 38.9%, respectively were obtained under the weekly, 2-weekly, and 3-weekly spray schedules. The highest economic returns for Dithane (71, 252 Shs/ha), Saprol (127,607 Shs/ha), and Folicur (236, 181 Shs/ha), were obtained under the 2-weekly, 2-weekly, and 3-weekly spray schedules. Rust control was associated with increased seed weight and number of filled pods per plant.

Key words: Glycine max, net benefits, rust severities

Introduction

Fungicides have been used to control soybean rust since the 1950's (Kitani, 1952). Indeed, several studies on fungicide screening and establishment of spray schedules have been conducted in several parts of the world where rust causes substantial damage (Kitani *et al.,* 1960; Hu *et al.,* 1975; Sudjadi *et al.,* 1977; Maiti *et al.,* 1982; Junqueira *et al.,* 1984). Most of these studies indicated yield benefit achieved through use of fungicides to control soybean rust. However, economic analyses of the use of these fungicide applications were often not done and yet this is essential for rationalization of fungicide usage.

In Uganda, soybean rust is a relatively new disease. In other parts of the world where the disease is endemic, fungicides are commonly used for control, especially in absence of resistant or highly tolerant cultivars (AVRDC, 1992). Unfortunately, no fungicides have been evaluated against rust in Uganda, and yet the disease is on the increase and the popular varieties are susceptible, implying destructive control is inevitable. We are also not certain whether recommendations based on trials conducted elsewhere are applicable to local conditions in Uganda. Differences in soybean growing areas with respect to climatic patterns and economic factors greatly influence the use of fungicides as a rust control option, so that fungicide recommendations are often location specific (Bromfield, 1984). It is therefore necessary that fungicide use as a control option against rust be carried out under our local conditions. Therefore, the objective of this study was to evaluate efficacies of three different fungicides and three spray regimes for the management of soybean rust in Uganda.

Materials and methods

The trial was conducted at Namulonge Agricultural and Animal Production Research Institute (NAARI), an area in central Uganda with high rust pressure (Kawuki *et al.*, 2002). The trial was conducted for three consecutive seasons, starting in second rains of 2000 (October 2000 - January 2001), first rains of 2001 (March - June), and second rains of 2001 (October 2001 – January 2002). Here after, these seasons are referred to as 2000B, 2001A, and 2001B, respectively. Nam 2, a popular, medium maturing soybean cultivar (112 days), but highly susceptible to rust (Kawuki *et al.*, 2002) was used in the study. Three fungicides, Dithane M-45 (contact wettable powder), Saprol (Triforine, systemic, Cynamid), and Folicur (Tebuconzole, systemic, Bayer Germany) were applied at rates of 2.5g l^{-1}, 2ml l^{-1}, and 1ml l^{-1}, respectively. Three spray regimes, weekly, 2-weekly, and 3-weekly intervals, corresponding to 5, 3, and 2 sprays a season, were evaluated. Spraying commenced at onset of the disease (when rust symptoms were seen on bottom third leaves) up to R6 growth stage. The crop growth stage was determined following (Fehr and Caviness, 1977). The control plots were not sprayed.

The experiment layout was a split-plot of a Randomised Complete Block Design with three replicates. The main plots comprised of the spray intervals, while the sub-plots were the fungicides. Each experiment plot had four rows 2 m long. Spacing between and within the rows was 60 cm x 5 cm, respectively. A 2 m alley was left between plots and replicates to minimize inter-plot interference. Two rows of Nam 2 were sown between replicates and around the experiment area to increase inoculum pressure. The experiment was kept weed-free by regular hand hoeing. Rust severity was assessed 14 days after the final spray on the upper third leaves of five randomly selected plants from the 2 middle rows of each plot. The 0-9 percentage severity scale, where 0= no disease, and 9= 90% disease plus defoliation was adopted (Walla, 1979 cited by Sinclair, 1982). At full maturity, two middle rows were harvested, sun-dried for 2 days, and then threshed. Plot yield was standardized to 12% moisture content (steinlite model 400-G tester, Stein Laboratories Inc., Kansas). Additionally, 100-seed weight for each plot was determined using a sensitive balance (Precision plus, TP series). Five plants were randomly selected from the remaining 2 rows, and used to determine number of pods/ plant, and the number of filled pods. The percentage of filled pods per plant was then computed.

The entire data were subjected to analysis of variance, using Genstat Computer software (Lawes Agricultural Trust, 1995). Means were compared using standard error of difference (SED). Additionally, an economic analysis to establish the benefit of the different fungicide applications was done. Mean yields for each fungicide treatment across the three seasons was used in the economic analysis. The profitability (net benefit) of each fungicide treatment was obtained following the CIMMYT (1988) procedure. The assumption was that rust was the major factor affecting soybean yield, but yields were reduced by 5% to account for crop management differences that would occur between farmer- managed and researcher-managed field conditions. Under the research-managed conditions, agronomic production practices are strictly adhered to, as opposed to the farmer-managed field conditions. The costs of the fungicide applications are presented in Table 1.

Results

Effect of fungicides on rust development

Rust severity as influenced by fungicide spray regimes are presented in Table 2. For all the spray regimes (weekly, 2-weekly, and 3-weekly), unprotected soybean (controls) had significantly higher rust severities than the rust-protected soybean. The descending trend of rust severities was control> Dithane> Saprol> Folicur (Table 2). It was only dithane-protected soybeans that had significant differences in rust severity between the spray schedules, observed during 2000B and 2001B, with weekly-protected soybean having significantly lower severities. Application of Folicur resulted into extremely low rust severities (10%), in both the 3-weekly and 2-weekly spray schedules

Effect of rust control on soybean yield

Fungicide treatments variously influenced the soybean yields (Table 3). For example, all soybean sprayed weekly yielded higher than the unprotected soybean. However, during 2001A, it was only Folicur-protected soybean that yielded significantly higher than the unprotected soybeans. For the 2-week interval spray schedule, it was only during 2000B and 2001B when rust protected soybean yielded significantly higher than the unprotected soybeans. For the 3-week interval schedule, it was only Folicur protected soybean that yielded significantly higher than the unprotected soybean except during 2001A (Table 3). On average, Dithane had the highest yield increase of 26.9% under the weekly spray schedule; followed by Saprol with 33.3% yield increase under the 2-week interval schedule; and then Folicur with an increase of 38.9% during the three week interval schedule.

Effect of rust control on yield components

Within the weekly spray schedule, rust protected soybean had significantly higher seed weight than the unprotected soybean (Table 4). However, during 2001B, it was only folicur-protected soybean that

Table 1. Cost of fungicide applications used in the cost benefit analysis[1].

Item	Cost (Ug. Shs.)	Total Variable cost
A) Unprotected soybean		
A1) Cost of seed	21, 000	
A2) Land preparation	180,000	
A3) Labor for planting	41, 400	
A4) Labor for weeding	124,200	
A5) Labor for harvesting	62,500	
A6) Labor for threshing	72, 916	
A7) Sub- total	502,016	502,016
B) Protected soybean		
B1) Labor for 5 sprays	104, 166	
B2) Labor for 3 sprays	62, 500	
B3) Labor for 2 sprays	41, 666	
B4) Depreciation of knapsack	12, 600	
B5) Labor for harvesting additional grain	62, 708	
B6) Labor for threshing additional grain	78,125	
C) Dithane M-45 protected soybean		
C1) 5 sprays	104, 166	A1+A2+A3+A4+B1+B4+B5+B6+C1 = 707,324
C2) 3 sprays	62, 499	A1+A2+A3+A4+B2+B4+B5+B6+C2 = 634,408
C3) 2 sprays	41, 666	A1+A2+A3+A4+B3+B4+B5+B6+C3 = 599,949
D) Saprol protected soybean		
D1) 5 sprays	250, 000	A1+A2+A3+A4+B1+B4+B5+B6+D1 = 816,699
D2) 3 sprays	150, 000	A1+A2+A3+A4+B2+B4+B5+B6+D2 = 700,033
D3) 2 sprays	100, 000	A1+A2+A3+A4+B3+B4+B5+B6+D3 = 641,699
E)) Folicur protected soybean		
E1) 5 prays	366, 665	A1+A2+A3+A4+B1+B4+B5+B6+E1 = 879,199
E2) 3 sprays	219, 999	A1+A2+A3+A4+B2+B4+B5+B6+E2 = 737,533
E4) 2 sprays	146, 666	A1+A2+A3+A4+B3+B4+B5+B6+E3 = 666,699

[1] Calculated on per hectare basis. 1USD= 1700 Ug. Shs.

Table 2. Percentage rust severities on upper third trifoliate of Nam 2 under different fungicides and spray regimes.

Treatment	2000B[5]			2001A			2001B		
	Weekly[4]	2-Weekly	3-Weekly	Weekly	2-Weekly	3-Weekly	Weekly	2-Weekly	3-Weekly
Control	72.0	78.6	78.6	80.0	80.0	80.0	72.9	76.0	76.8
Dithane-M45	18.4	53.3	55.3	77.3	77.3	76.6	40.7	58.3	55.9
Saprol	4.0	16.0	24.5	38.0	42.0	44.7	20.0	24.0	31.5
Folicur	0	0	0	6.6	7.66	25.3	8.3	8.8	17.6
SED[1]		7.73			8.78			9.48	
SED[2]		7.95			9.18			6.45	
CV (%)[3]		29.1			21.2			23.5	

[1]separates means of treatments within regimes, [2] separates means of treatments between regimes, [3] Coefficient of variation, [4]Weekly, 2-weekly, and 3 weekly correspond to 5, 3, and 2 sprays, respectively, [5]A and B correspond to first (March-June) and second (October-January) seasons, respectively.

Table 3. Seed yield (kg ha⁻¹) of a rust-susceptible soybean variety Nam 2 under different fungicides management regimes[1].

Treatment	2000B[6]			2001A			2001B		
	Weekly[5]	2-Weekly	3-Weekly	Weekly	2-Weekly	3-Weekly	Weekly	2-Weekly	3-Weekly
Control	964	974	998	744	671	945	984	990	998
Dithane-M45	1327 (26.3)	1276 (23.3)	1085 (9.8)	1083 (27.3)	1015 (22.5)	1001 (21.4)	1354 (26.8)	1424 (30.4)	1250 (20.8)
Saprol	1519 (35.6)	1675 (41.6)	1154 (15.2)	1086 (27.5)	1362 (42.2)	1331 (40.9)	1310 (24.4)	1319 (24.9)	1354 (26.8)
Folicur	1606 (39.1)	1744 (43.9)	1659 (41.0)	1606 (51.0)	1392 (43.4)	1668 (52.8)	1493 (33.6)	1528 (35.2)	1424 (30.4)
SED[2]		208.5			355.9			172.1	
SED[3]		204.2			378.0			181.2	
CV (%)[4]		18.4			41.3			16.9	

[1] percentage yield increase in parentheses, [2] separates means of treatments between regimes, [3] separates means of treatments within regimes, [4] Coefficient of variation, [5] Weekly, 2-weekly, and 3 weekly correspond to 5, 3, and 2 sprays, respectively, [6] A and B correspond to first (March-June) and second (October-January) seasons, respectively.

had significantly higher seed weight than the unprotected soybean. For the 2-weekly and 3-weekly spray schedules, it was only soybean protected with Saprol and Folicur that had significantly higher seed weight than the unprotected soybean.

For each fungicide, no significant differences were observed in seed weight between the different spray regimes, except during 2000B, with soybean protected with Dithane or Saprol (Table 4). For all the three spray schedules, seed weight followed the descending trend with control< Dithane< Saprol< Folicur. Seed weight was significantly lower ($P<0.001$) during 2001A in relation to other seasons.

The applied fungicides also variously influenced the filled pod percentage (Table 5). In the case of the weekly spray schedule, all rust protected soybeans had significantly ($P<0.005$) higher filled pods than the unprotected soybeans, except during 2001B. However, for the 2-weekly and 3-weekly spray schedules, it was only soybean protected with either Saprol and Folicur that had significantly higher filled pods than the unprotected soybean (Table 5). For each fungicide treatment, there was no significant difference in percentage filled pods between the three spray schedules, except with Dithane protected soybeans during 2001B. Results indicate that filled pods were significantly lower ($p<0.001$) during 2001A

Cost benefit analysis

The rust-protected soybean exhibited varying levels of profitability (Tables 6 and 7). Although the unprotected soybean also gave some positive net benefits, these were much lower than the rust-protected soybean, especially for soybean protected with either Folicur and Saprol sprays (Table 7). Highest net benefits for Folicur, Saprol, and Dithane were 236, 181 Shs ha^{-1}, 127, 607 Shs ha^{-1} and 71, 252 Shs ha^{-1}, respectively. These net benefits were a result of 3-week interval, and 2-week interval spray schedules, respectively (Table 7). However, Saprol showed negative net benefits under the weekly-spray schedule.

Discussion

The applied fungicides Dithane M-45, Saprol and Folicur effectively controlled rust infection, and increased soybean yields significantly. However, the level of control depended on the fungicide used and the spray interval. Dithane-M45, which is a protectant wettable powder, provided its best protection when applied at a weekly interval (5 sprays) from disease onset (early pod formation) to full seed formation. On the other hand, Saprol and Folicur, both systemic, showed best protection with 3 and 2 sprays, respectively from disease onset to full seed formation.

Protectant fungicides are plant-surface barriers and are thus ineffective against established infections. Therefore, for effective use they must either be applied before the pathogen enters the plant or applied more frequently during the epidemic to replace the chemical washed-off by the rain. On the other hand, systemic fungicides enter the plant and kill established infections, and are thus more effective against established infections of the rust pathogen *Phakopsora pachyrhizi* than the protectant fungicides. Studies conducted elsewhere (Kitani *et al.*, 1960; Torres and Quebral, 1976; Chen and Nguyen, 1988), indicated that significant differences in rust severity and yield occur between rust-protected and unprotected soybeans, but with systemic fungicides being more effective against rust than protectant fungicides (Hu *et al.*, 1975; Nakamura *et al.*, 1981; Junqueira *et al.*, 1984).

In terms of spray schedule, the study has shown that systemic fungicides require less number of sprays than the protectant fungicides (2 or 3 sprays). As opposed to protectant fungicides, frequent application of systemic fungicides i.e., on a weekly interval, appears to rapidly accumulate toxic residues in the plant that may decrease its yield potential. Lower soybean yields obtained from weekly sprays as compared to two or three weekly sprays gives some credence to this fact. Comparable results

Table 4. Comparison of 100-Seed weight (g) of a rust susceptible soybean variety Nam 2 under different fungicide treatments.

Treatment	2000B[4]			2001A			2001B		
	Weekly[5]	2-Weekly	3-Weekly	Weekly	2-Weekly	3-Weekly	Weekly	2-Weekly	3-Weekly
Control	10.4	10.7	9.9	8.5	8.5	8.1	10.4	10.9	10.8
Dithane	13.4	11.3	11.0	9.6	9.3	8.9.3	11.1	11.0	11.3
Saprol	13.5	13.8	12.1	11.0	11.0	12.1	10.9	10.9	10.9
Folicur	13.5	13.9	13.8	13.9	14.1	13.6	12.6	13.0	12.4
SED[1]		0.60			0.86			0.34	
SED[2]		0.61			0.93			0.35	
CV (%)[3]		6.1			7.2			3.8	

[1] separates means of treatments between regimes, [2] separates means of treatments within regimes, [3] Coefficient of variation, [4] A and B correspond to first (March- June) and second (October-January) seasons, respectively, [5] Weekly, 2-weekly, and 3 weekly correspond to 5, 3, and 2 sprays, respectively.

Table 5. Comparison of filled pods (%) of a rust susceptible soybean variety Nam 2 under different fungicide treatments.

Treatment	2000B[4]			2001A			2001B		
	Weekly[5]	2-Weekly	3-Weekly	Weekly	2-Weekly	3-Weekly	Weekly	2-Weekly	3-Weekly
Control	79.8	79.9	74.9	56.4	57.6	57.1	91.5	89.5	91.2
Dithane	91.5	85.5	78.5	65.3	68.7	68.5	95.3	87.8	95.2
Saprol	97.2	94.6	93.8	72.5	78.0	70.0	95.3	93.7	91.8
Folicur	90.0	91.8	93.1	84.5	87.1	78.5	93.6	95.2	96.0
SED[1]		4.04			5.02			2.06	
SED[2]		4.06			5.39			2.31	
CV (%)[3]		5.7			9.4			3.1	

[1] separates means of treatments between regimes, [2] separates means of treatments within regimes, [3] Coefficient of variation, [4] A and B correspond to first (March-June) and second (October-January) seasons, respectively, [5] Weekly, 2-weekly, and 3 weekly correspond to 5, 3, and 2 sprays, respectively.

were observed by Nakamura *et al.* (1981): best control of rust was achieved when fungicides were applied 2 or 3 times, from young pod to full seed formation.

The economic analysis justifies 2-weekly spray schedule for Dithane, and 2-weekly and 3-weekly spray schedules for Saprol and Folicur, respectively. The lower net benefits observed with weekly and 3-weekly spray schedules of Dithane as compared to the unprotected soybean; suggest that fungicides used in management of soybean rust must be both effective and economically justifiable. Thus, the benefit arising from fungicide application must by far surpass their application costs. Earlier studies reported higher returns from 2 or 3 applications of bayelaton (systemic) as compared to 5 applications of manzate-D, a protectant fungicide (Pupipat *et al.*, .1982). The marginal net benefits obtained from the unprotected soybean appear not to be sustainable when the epidemic becomes more serious in the near future. This illustrates that when highly rust-tolerant cultivars are identified, they can be used for control of soybean rust and may not require fungicide protection.

We conclude that fungicides can provide an economical control option for combating and or minimizing yield losses attributable to soybean rust in Uganda. The profitable fungicide regimes can be utilised by the Uganda Seed Project which is mandated to produce certified seed or even by the farming community which at times prefer growing rust susceptible intolerant soybean varieties. We further recommend that more fungicides (especially systemics) be screened, but with spray schedules being manipulated to comprise of 3, 2 or even 1 spray(s) per growing season.

Table 6. Actual and adjusted yield used in economic analysis[1].

Treatment	Actual yield (kg ha^{-1})	Adjusted yield (kg ha^{-1})
Control	968	919.6
Dithane M 45 X 5 sprays	1325	1258.7
Dithane M 45 X 3 sprays	1238	1176.1
Dithane M 45 X 2 sprays	1112	1056.4
Saprol X 5 sprays	1305	1239.7
Saprol X 3 sprays	1452	1379.4
Saprol X 2 sprays	1280	1216.0
Folicur X 5 spray	1568	1489.5
Folicur X 3 spray	1555	1477.5
Folicur X 2 spray	1584	1504.8

[1] means of yields across 3 seasons. Yields reduced to 5% to account for management differences between farmer and experimental conditions.

Table 7. Cost benefit analysis of different fungicides and spray regimes used in the management of soybean rust[1].

Treatment	Adjusted yield (kg ha^{-1})	Gross Benefit GB) Ug. Shs.	Total Variable Cost (TVC) Ug. Shs.	Net Benefits (NB) Ushs.
Control	919.6	551,760	502,016	49,744
Dithane X 5 sprays	1258.7	755,2220	707,324	47,896
Dithane X 3 sprays	1176.1	705,666	634,408	71,252
Dithane X 2 sprays	1056.4	633,840	597,949	35,891
Saprol X 5 sprays	1239.7	743,850	816,699	-72,849
Saprol X 3 sprays	1379.4	827,940	700,033	127,607
Saprol X 2 sprays	1216.0	729,600	641,699	87,901
Folicur X 5 sprays	1489.5	893,700	879,199	14,501
Folicur X 3 sprays	1477.5	886,500	737,533	148,967
Folicur X 2 sprays	1504.8	902,880	666,699	236,181

[1] Calculations based on per ha. USD=1700 Ushs. Gross Benefit = yield x price (Ushs 600), this was the farm gate price per kg of soybean that a farmer would receive. Net Benefit = GB- TVC.

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