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Optimum fertilizer application mitigates the effect of angular leaf spot disease in common beans

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Abstract

Common bean production in Uganda is constrained by angular leaf spot (ALS) disease (*Pseudocercospora griseola*). Without durable resistance to the disease and concerns surrounding pesticide use, management of ALS depends on cultural practices, which unfortunately have not been very effective. Improved fertilization of crops has been used to manage some diseases in crops and thus could be a valuable addition to the integrated management package for ALS disease. The effect of NPK on common bean growth and ALS severity was studied on variety K131 at Makerere University Agricultural Research Institute, Uganda in 2020 and 2021. NPK levels 0, 60, 120, 180 and 240 kg ha^{-1} were tested in the field, with three replication. Disease progressed fast under low NPK rates, reaching a plateau at high rates. AUDPC ranged from 142.5 to 183 in 240 and 0 kg $NPKha^{-1}$ plots, respectively. Yield parameters were significant ($P<0.001$) for, and increased with amount of NPK. Mean pod number ranged from 13.3 to 21.8 in 0 and 240 kg $NPKha^{-1}$ treatments, respectively. Seed number per pod ranged from 4.75 to 5.3; while 100 seed weight ranged from 22.5 gm to 24.1 gm. Plant dry matter followed the same trend and ranged from 29.7 to 53.2 gm/plant. Marketable grain yield ranged from 1.53 to 3.27 t/ha. Relative yield loss increased as NPK reduced or as ALS AUDPC increased with the highest (53.2%) recorded for zero NPK. Multiple regression resulted into a significant NPK amount effect ($R^2 = 0.991$; $P = 0.018$) and a non-significant ($P = 0.365$) AUDPC effect on relative yield loss. NPK application, therefore, does not affect ALS disease but cancels out its effects at optimal fertilizer levels. NPK applications should be deliberately integrated into bean production to minimise the effects of ALS disease.

Key words: AUDPC, diseases severity, NPK, *Phaseolus vulgaris*, *Pseudocercospora griseola*

Introduction

Common bean (*Phaseolus vulgaris* L.) is the most important (Goettsch *et al*., 2016) and most widely grown and consumed legume in Uganda (Mauyo *et al.*, 2007). Its popularity arises from the fact that it is easy to grow, has a short maturity period and fits in several cropping systems (David *et al*., 2000). In addition, it is highly nutritious, supplying cheap proteins to consumers (Broughton *et al*., 2003). The crop is thus important for food security and income to smallholder rural households. Common bean production in Uganda is, however, constrained by several factors including reduced soil fertility, poor agronomic practices, lack of seed of improved varieties, moisture stress, flooding, competition with weeds, post-harvest pests, and damage due to field pests and diseases (Sinclair and Vadez, 2012; Mukankusi *et al*., 2015). As a result, its yield is very low, averaging 625 kgha^{-1} compared with a potential of 1750 – 3750 kgha^{-1} (MAAIF, 2019).

Angular leaf spot (ALS) disease caused by a deuteromycete fungus *Pseudocercospora griseola* is one of the most destructive disease of common bean in Uganda (Ddamulira *et al*., 2014) and causes significant yield losses throughout bean growing areas of the country and elsewhere. Several studies have reported yield losses due to ALS ranging from 30-80% in countries in the USA, South America and Africa (Wortman *et al.*, 1998; Muthomi *et al*., 2011; Wani *et al*., 2022;). In the Lake Victoria basin of Uganda, Paparu *et al*. (2014) reported a loss of 54% due to the disease.

The fungus attacks all aboveground parts of the plant including leaves, leaf petioles, stems and pods. On primary leaves, it produces round and big lesions with concentric rings. On trifoliate leaves *P. griseola* causes numerous gray or brown spots surrounded a yellow margin. These spots become necrotic and assume the angular shape characteristic of the disease. These spots may coalesce destroying substantial leaf area and resulting in chlorosis and defoliation (Saettler, 1994). On the pod and stems, the fungus causes dark oval to circular lesions. Pod infection results into shriveling and discoloration of seed reducing seed quality and health (Pastor-Corrales *et al.,* 1998). Infected seeds transmit the disease (Wani *et al*., 2022). The disease is favoured by a wide range of temperature with the optimum being 24^{o}C, and a fluctuating low and high relative humidity (Stenglein *et al.*, 2003).

It has been suggested that an integrated approach be used in the management of ALS (Paparu *et al*., 2014). Such an approach should include the use of genetically resistant varieties (Mahuku *et al.*, 2009), disease free seed, crop rotation, fungicide sprays (Paparu *et al.*, 2014; Mekonen, 2017), and growing mixed varieties (Olango *et al*., 2016). Despite implementing some of these practices, the disease continues to cause much damage. Use of resistant varieties has been limited by the fact that they are difficult to develop due to the highly variable nature of the pathogen (Mahuku *et al*., 2002). Thus, there are no varieties with durable resistance to the pathogen (Wagara *et al*., 2011). Use of fungicides in disease management is said to be associated with human health and environmental problems (Ghorbani *et al*., 2009) thus the need for their cautious use. Farmers in Uganda mostly save and recycle own seed (Larochelle *et al*., 2018). Such seed is often unclean and may carry seed-borne pathogens including *P. griseola*. In Uganda, other practices such as crop rotation are limited by lack of enough land by many households. Consequently, most crop production fields in Ugandan households have been over-cultivated and have lost fertility. In soils for such households, the effect of crop diseases is very pronounced (Chaboussou, 2004). Therefore, there is need to devise other management practices to supplement the currently recommended package. Improved soil fertility improves crop yields through direct effects on yield parameters (Sanyang *et al*., 2019) but also indirectly through its effect on crop diseases (Gupta *et al*., 2017). In the presence of disease, applied nutrients improve crop productivity through facilitating continuous production of foliage that ensures that there is sufficient photosynthetically active leaf area.

Therefore, maintaining sufficient soil nutrients may be important in mitigating the effects of crop diseases including ALS. In the Lake Victoria crescent of Uganda, nitrogen, phosphorus and potassium were reported to be the most limiting soil nutrients (Kyomuhendo *et al*., 2018). These nutrients are unfortunately the most important for common bean productivity (Marschner, 2012). Addition of NPK to soils improves bean yield (Paparu *et al*., 2014; Sanyang *et al*., 2019) but also has high potential to reduce the impact of ALS disease. Although optimum fertilizer rates for bean production in a disease free environment have been suggested in Uganda (Kayuki *et al*., 2012), the effect of improved soil nutrients on beans infected with *P. griseola* has not been quantified. This study, therefore, was carried out to determine the effect of NPK fertilizer on severity of ALS and bean yield.

Materials and methods

Study area

The study was conducted at the Makerere University Agricultural Research Institute, Kabanyolo (MUARIK) in three consecutive season i.e., March – June 2020, September - December, 2020 and March – June 2021. MUARIK is located at an altitude of 1200 metres above sea level in the humid Lake Victoria belt, and receives a mean annual bimodal rainfall of about 1,270 mm (Smit *et al.*, 1997) with mean minimum and maximum temperatures of 17° C and 27°C, respectively. Before planting, physical and chemical analysis of soil in the experimental field was carried out to determine the status of soil nutrients. Soil pH, soil organic matter content, total N and extractable P were determined using methods described by Okalebo *et al.* (2002). Exchangeable bases were extracted using ammonium acetate and quantified by flame photometry (K^+, Na^+) and atomic absorption spectrophotometer (Ca^{2+}, Mg^{2+}). Particle size distribution was determined by the hydrometer method and soil texture assigned using the soil textural triangle. Results of this analysis are shown in Table 1. The experimental field had a history of continuous cropping with different crops including beans ensuring that *P. griseola* inoculum was high in the study plots.

Experimental setup

An angular leaf spot susceptible variety K131 was used in the study. Beans were grown in 6-row plots, with each row measuring 4 m long. The plot size was 8 m^2. The spacing was 40 x 10 cm, with one plant per hole. Prior to planting, fertilizer (NPK 17:17:17) was applied in the different plots to supply an equivalent of 0, 60, 120, 180 and 240 kg of NPK/ha. The experimental design was a randomised complete block (RCBD) with 3 replicates.

Data collection

Data were collected on foliar ALS severity, pod number, number of grains per pod, total grain weight, weight of marketable grain, and 100 seed weight. Yield data were used to compute relative percent yield loss (RYL %). Relative percent yield loss was computed according to Guji *et al.* (2019) as shown below:

$$\text{RYL}(\%) = \frac{(\text{Y1} - \text{Y2})}{\text{Y1}} \text{ X } 100$$

Where: RYL = relative bean grain yield loss; Y1 = maximum mean bean grain yield of the best treatment in the experiment; and Y2 = mean bean grain yield of the other treatments.

ALS severity was scored beginning at 30 DAP (corresponding to growth stage R2) at 7-day intervals until physiological maturity. ALS severity was scored on ten plants randomly selected from the four inner rows using a 1-9 scale (Inglis *et al.*, 1988). In this rating, 1 = 1-10% leaflet with lesions, 3 = 11-25% leaflet with lesions, 5 = 26-50% leaflet with lesions, 7 = >50% leaflet with lesions and 9 = severe disease with

Table 1. Soil properties of the experimental field at MUARIK, February 2020A

	pH	OM	N	Av. P (mg/kg)	K	Na	Ca	Mg	%Sand	%Clay	%Silt
		— — % ——			— — — Cmoles/kg — — —				— Texture — — — —		
	5.3	2.74	0.15	8.22	0.45	0.13	3.7	1.14	64.5	19	16.5
Critical values	5.0	3.0	0.25	15.0	0.4	1.0>	1.00	0.80			

defoliation. Disease severity scores were converted to area under disease progress curve (AUDPC) before analysis. AUDPC was calculated according to Campbell and Madden (1990) as shown below:

$$AUDPC = \sum_{i=1}^{n-1} \left(\frac{y_i + y_{i+1}}{2} \right) (t_{i+1} - t_i)$$

AUDPC = area under disease progress curve; n = total number of observations, yi = ALS score at the ith observation, and t = time at the ith observation.

Total plant dry matter

At physiological maturity, ten plants were randomly and carefully uprooted from each plot and used for dry matter determination. After cleaning them of all soil on roots under running tap water, they were put in an oven at 70^{o}C and dried to constant weight. They were then weighed and the mean computed.

Pod number, number of seeds per pod and 100 seed weight

To determine number of pods per plant and number of seeds per pod, ten plants were randomly selected and harvested from 4 middle rows in each plot and dried under the sun. The total number of pods on the ten plants were counted and averaged per plant. These pods were threshed and number of seeds counted. These were then averaged to seeds per pod. From the dried seed, 100 seeds were randomly selected and weighed.

Total and marketable yield

To determine total grain yield per plot, the rest of the plants in a plot were harvested, dried, threshed and seed weighed. The obtained weight was converted into yield per ha. The harvested grains were then sorted to remove all wrinkled and blemished seeds. The remaining beans were then weighed and converted into marketable yield per ha.

Data analysis

Data were subjected to 2-way analysis of variance (ANOVA) in Genstat Release 14.1. The seasonal effects on all parameters were not significant, and therefore seasons were combined during analysis. Where significant treatment effects were observed, means were separated using the Least Significant Difference (LSD) test at P = 0.05. Multiple regression analysis was carried out to determine the relative contribution of different studied parameters to yield and ALS severity.

Results

Angular leafspot progress and AUDPC

Disease appeared on bean trifoliates in all treatments and was clearly visible by 30 days after planting (DAP). This time coincided with growth stage R1 (flowering). The season effect on ALS severity was non-significant ($P > 0.05$). Amount of NPK applied was significant ($P \leq 0.001 - 0.017$) for ALS severity throughout the trial. For the 0, 60 and 120 $kgha^{-1}$ NPK treatments, ALS severity progressed gently with a reducing gradient reaching plateaus at around 55 DAP. On the other hand, the 180 and 240 $kgha^{-1}$ NPK treatments exhibited gentle sigmoid relationships, steadily rising from around a mean score of 2.5 and peaking at 60 DAP. At this point, which coincided with physiological maturity, ALS severity scores for all NPK treatments had risen above 7 (Fig. 1).

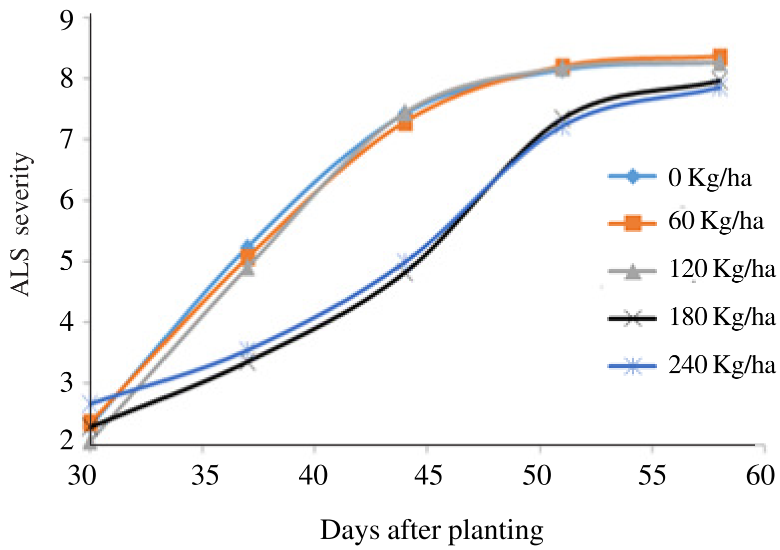

Figure 1. Progress of common bean angular leaf spot disease as influenced by varying amounts of NPK fertilizer at MUARIK, Uganda, 2020-2021

The season effect was not significant ($P = 0.819$) for AUDPC. However, the effect of amount of NPK applied was highly significant ($P < 0.001$) for AUDPC. AUDPC ranged from 142.5 – 183.0 with lowest and highest values recorded from applications of 240 and 0 kg NPK ha^{-1}, respectively (Fig. 2). The highest AUDPC value was not significantly different from those recorded in plots that received 60 and 120 kg NPK ha^{-1} (Fig. 2). It is noteworthy that although the final ALS mean severity score was high (>7.85) for all treatments, AUDPC values for the two highest NPK application rates were low compared to those from the lower rates.

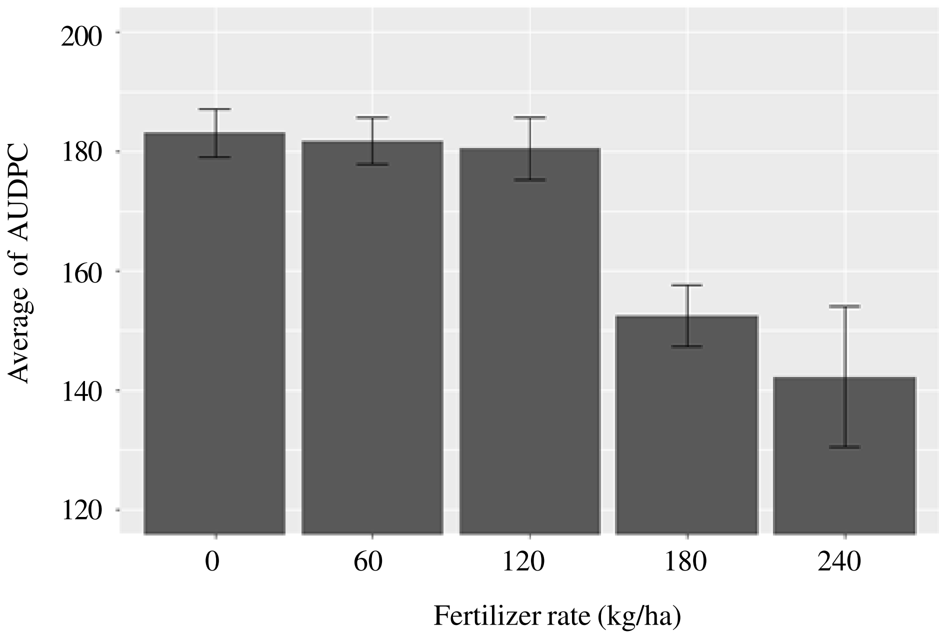

Figure 2. Bean angular leaf spot area under disease progress as influenced by varying amounts of NPK fertilizer at MUARIK, Uganda, 2020-2021.

Yield and yield parameters

The effect of NPK on common bean yield and yield parameters is given in Table 2. These parameters were all significantly ($P < 0.001$) affected by the amount of NPK applied. Mean number of pods per plant increased with increasing applied NPK. The least mean pod number per plant (13.3 pods per plant) was recorded in plots that didn't receive any NPK while the highest (21.8 pods per plant) was produced by plants that received the maximum amount of NPK. Mean seed number per pod increased as amount of NPK increased. However, compared to pod number per plant, the range of number of seeds per pod was only 0.55. The least number of seed per pod (4.75 seeds) was also recorded in plots that were not fertilized while the highest (5.3 seeds) was obtained from plots that received maximum NPK. Mean of 100 seed weight also increased as amount of applied NPK increased and ranged from 22.5 gms in unfertilized plots to 24.1 gms in plots that received 180 kg NPK/ha. With the exception of the control, the rest of the 100 seed weights were not significantly different.

Mean plant dry matter was between 29.7 and 53.2 gm/plant. The lowest and highest dry matter were obtained from plots that received no NPK and those that received the highest amount of NPK, respectively. All plant dry matter values were significantly different from each other (Table 2).

Table 2. Common bean yield and yield components as influenced by varying amounts of NPK fertilizer in the presence of angular leaf spot disease at MUARIK, Uganda, 2020-2021

NPK applied (kg/ha)	Grain yield and yield components				
	No. of pods/plant	No. of seeds/pod	100 seed weight (gm)	Plant dry matter matter (gm)	Marketable grain yield (t/ha)
0	15.3	4.75	22.5	29.7	1.53
60	15.7	4.82	23.6	36.5	2.04
120	19.0	4.96	24.0	39.5	2.58
180	19.5	4.86	24.1	42.9	3.00
240	21.8	5.30	23.8	53.2	3.27
Mean	**18.3**	**4.94**	**23.6**	**40.4**	**2.48**
LSD	4.422	0.243	0.68	0.19	0.15
P(0.05)	<.001	<.001	<.001	<.001	<.001
CV (%)	14.5	5.1	3	17.3	6.4

Marketable grain yield was significantly (P<0.001) affected by the amount of NPK applied and increased as amount of applied NPK increased. The least marketable yield (1.53 t/ha) was obtained from plots that were not fertilized. This was progressively followed by plots that received 60, 120, 180 and 240 kg $ha^{-1}$with the highest marketable grain yield of 3.27 t/ha obtained from plots that received the highest amount of NPK (Table 2).

Relationships between amounts of NPK applied and AUDPC

The relationships between AUDPC and marketable yield are shown in Figure 3. Generally, marketable yield reduced as AUDPC increased, but the relationship was not linear. Marketable grain yield was highest at the lowest AUDPC, gradually reducing in a linear manner as AUDPC increased until 180.5 then dropping sharply to 1.5 $kgha^{-1}$ at an AUDPC value of 183.0.

Relationship between NPK, AUDPC and relative yield loss (%)

Yield loss was computed for each of the fertilizer amount applied and AUDPC recorded. The relationship between mount of NPK applied and relative yield loss was negative, linear and strong and significant ($R^2 = 0.9885$). The highest yield loss was 53.2% and was obtained in plots that didn't receive any fertilizer. This gradually dropped as applied NPK increased (Fig. 4A). Relative yield loss was 0% at the

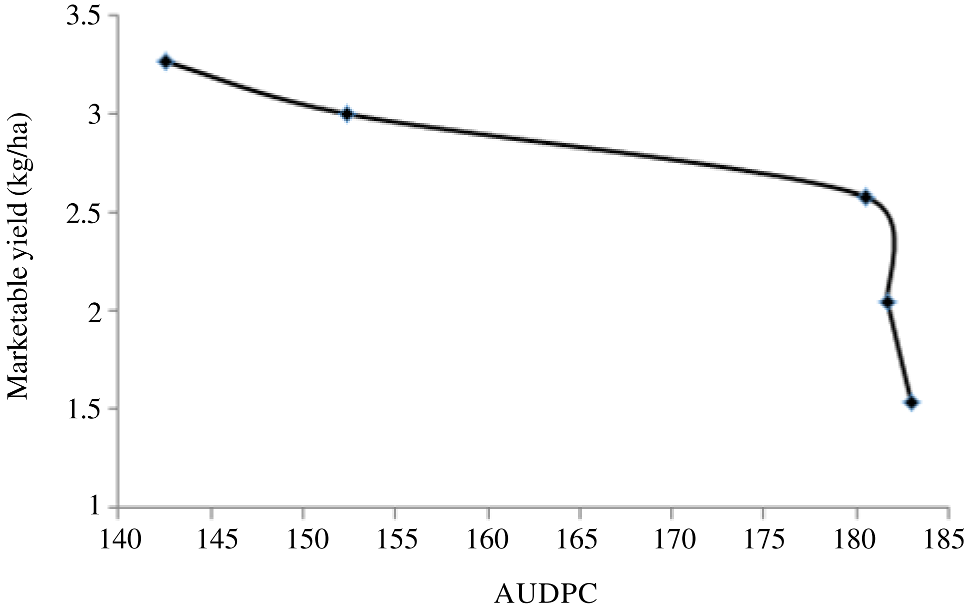

Figure 3. Relationship between angular leaf spot AUDPC and marketable bean yield on common beans grown at MUARIK, Uganda, 2020-2021.

lowest AUDPC and increased gradually to 20% at AUDPC of 180.5. Thereafter, it rapidly shot up to the highest value (53.2%) with a very small change in AUDPC (Fig. 4B). Multiple regression analysis showed a significant negative NPK amount effect (R^2 = -0.991; P=0.018) and a non-significant (P>0.05) AUDPC effect on relative yield loss. The regression equation was:

Y = 91.2 - 0.21AUDPC - 0.26NPK.

Discussion

To determine the effect of improved soil nutrients on beans in the presence of angular leaf spot disease, bean grain yield, bean growth parameters and ALS progress were recorded following application of different amounts of NPK fertilizer (17:17:17) to the crop. Soil in the experimental plots had been continuously cropped to different crops including beans and was thus poor in nutrients. Amount of organic matter, nitrogen, available phosphorus and sodium were all below critical levels for optimum crop productivity (Table 1). Angular leaf spot disease appeared in all plots irrespective of amount of NPK applied. The disease appeared in all treatments and progressed steadily until physiological maturity. Early in the season, disease severity increased faster in plots where no or low amounts of NPK were applied while in plots with high amounts of NPK, disease severity was initially slow, but increased towards the end

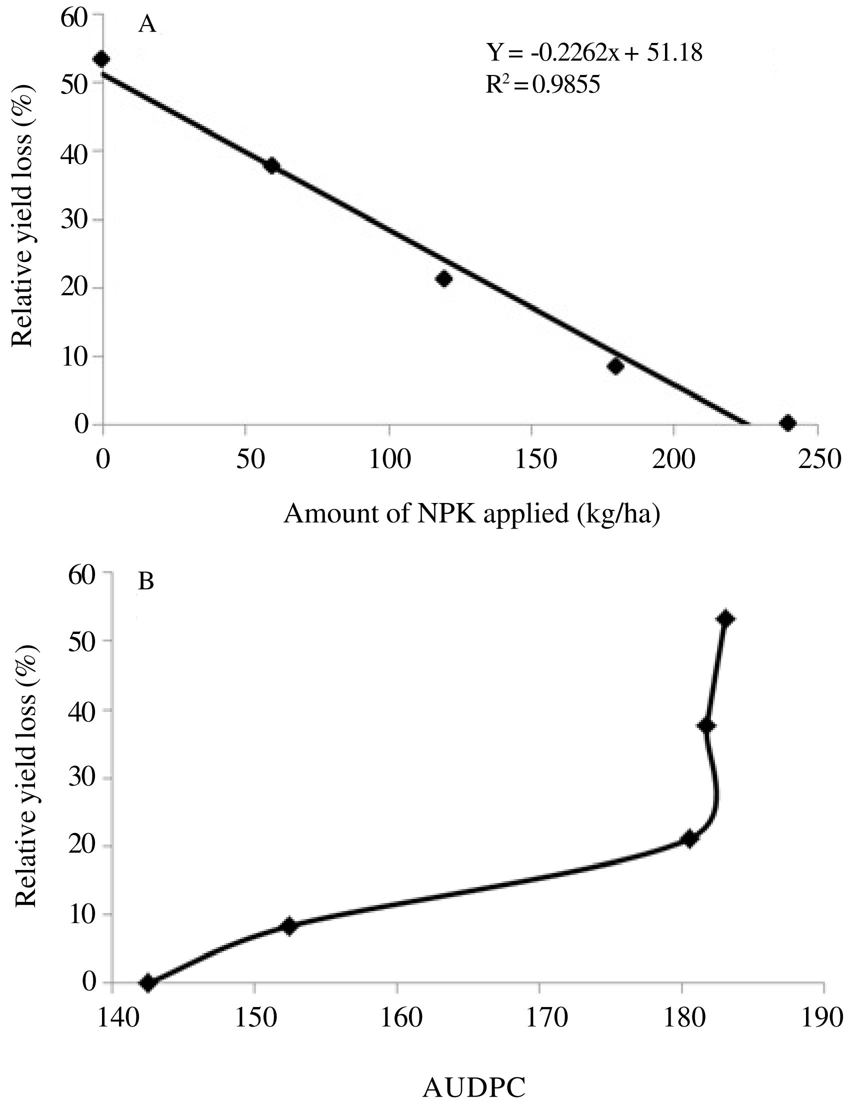

Figure 4. Effect of amount of applied NPK (A) and angular leaf spot disease AUDPC (B) on relative bean yield loss at MUARIK, Uganda, 2020-2021.

of the season, to levels similar to those where no or low amount of fertilizer was added. This is why AUDPC recorded on plots that were well fertilized was significantly lower than where fertilizer was absent or low despite all treatments recording high final ALS severity scores. This may be explained in two ways. First, during the vegetative growth period, well fertilized crops produced bigger and more vigorous leaves, resulting in less infected area compared to crops that received less fertilizer. Towards physiological maturity when no more leaves were being produced, disease severity increased very fast in these treatments to levels recorded in poorly fertilized plots. Secondly, although in some crop pathosystems, disease increases with increase in applied fertilizers (Datnoff, 1994; Johnson, 2015); in some systems, fertilizers slow down disease progress. Dordas (2008) and Fagard *et al*. (2014) reported that disease progress in plants caused by necrotrophic fungi such as *Pseudocercospora griseola* and *Alternaria* spp. tend to be slow in well fertilized soils because such fungi find it more challenging to kill host tissue when hosts are better nourished. Olesen *et al*. (2003) also reported that mineral NPK fertiliser resulted in lower Septoria blotch (*Septoria tritici*) in wheat. On potato, MacKenzie (1981) reported that under-fertilization of N can lead to an increase in early blight (*Alternaria solani*). Long and TeBeest (2000) investigated the effect of nitrogen fertilization on disease progress of rice blast (*Pyricularia grisea*) and reported a decline in severity.

All yield related parameters were significantly influenced by the amount of NPK applied. Several studies have reported significant increase in common bean yield with application of fertilizers (Zucareli *et al*., 2006; Pela *et al*., 2009; Sanyang *et al*., 2019). Nitrogen is essential for the production of many plant cellular components and supporting plant metabolic processes such as photosynthesis (Huber and Thompson, 2007; Havlin *et al*., 2009). Phosphorus stimulates root growth and is thus responsible for formation of a good root system. It is also an important constituent of nucleic acids and promotes the formation of pods in legumes (Prabhu *et al*., 2007). All these improve plant growth. Potassium plays a role in formation of proteins and carbohydrates (Hariyadi *et al*., 2019). For these reasons, the relationship between amount of applied NPK and marketable yield was strong, linear and positive.

Marketable yield reduced with increasing AUDPC, although the relationship was not linear. AUDPC values beyond 180 produced a very sharp decrease in marketable yield. This sharp decrease may imply that ALS was not solely responsible for the decrease in bean yield. This scenario can be explained by the effect of NPK on bean growth. ALS is expected to reduce yield in a linear relationship in a soil low in essential nutrients. Indeed, in this study, the relationship between AUDPC and marketable yield was linear at low levels of applied NPK. But at high NPK application rates, the effect of improved nutrition canceled out the negative effect of ALS disease. The low yield with low applied NPK (and high ALS severity) can partly be explained by the low bean effective leaf area due to poor nutrition and high disease severity. Healthy leaf area influences amount of intercepted radiation and thus photosynthesis, which in turn affects crop yield. In studies to investigate the relationship between ALS severity, AUDPC, healthy leaf area index, intercepted radiation, healthy leaf area duration (HAD), total healthy leaf area absorption (HAA), and yield of *Phaseolus* beans infected with *P. griseola,* Bergamin-Filho (1997) reported that yield was more a result of the leaf area of a crop at a particular time; but acknowledged that the interaction with nutrient levels may make yield prediction difficult. Indeed, multiple regression analysis showed that in the presence of ALS disease, applying NPK significantly reduced bean yield loss while disease itself did not.

Conclusions

The findings show that application of NPK fertilizer does not influence ALS severity but if applied optimally, it has beneficial effects to the plant that outweigh the negative effects of the disease. It is, therefore, recommended that in areas with high incidence of *P. griseola*, NPK applications be deliberately integrated in the bean production system to minimise the effects of ALS disease.

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