DEVELOPMENT OF DECISION SUPPORT TOOLS FOR INTEGRATED MANAGEMENT OF POTATO LATE BLIGHT IN THE HIGHLANDS OF UGANDA

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SUMMARY

Late blight (*Phytophthora infestans*) accounts for the greatest contribution to potato crop loss in tropical highlands particularly in Uganda. Consequently, field experiments to develop appropriate late blight management technologies for highlands were conducted at Kalengyere Research Station, 01°13.2′S, 020°47.8′E, at 2450 m above sea level in south western Uganda. The experiments were conducted for six cropping seasons, two per year but with overlapping potato crop cycles due to different planting dates, from 2002 to 2004. The objectives of the experiments were to; i) characterize the resistance of three potato varieties in Uganda under natural uncontrolled late blight epidemics, ii) develop late blight epidemic onset prediction models befitting continuous potato planting, iii) develop, test and recommend a logical integration of cultivar resistance, date of planting, protectant and systemic fungicide based on action threshold for late blight management, and iv) develop disease severity-yield and yield loss models befitting the continuous potato cropping system characteristic of most tropical highland agro-ecosystems. The first cropping seasons in south western Uganda starts in late February and ends in early July while the second begins in late August and ends early January.

Data revealed that the number of days from potato planting to disease onset among non-fungicide sprayed potato was highly influenced by the date of planting than potato cultivar. Late blight appeared earlier during the first than second cropping season and generally earlier on cv. Victoria than cvs. NAKPOT4 and NAKPOT5. There was a delay of 7-11 days in disease-onset between successive crop cycles within a cropping season and 11-13 days in counterpart crop cycles between the two cropping seasons per year. Late blight progressively appeared early with delay in planting in each cropping season. By the last planting dates, *i.e.* 12th April or 3rd November, for the first and second cropping season per year, respectively, disease was evident within 26±2 days after planting irrespective of potato variety. Late blight onset for a given crop cycle per planting date was predicted as function of cumulative hours with relative humidity ≥90% and accumulated rain days both computed from 1st March or 1st September but not from the actual planting date of a given crop cycle. The prediction models accounted for 73.3 and 98.8% of the observed variability in disease onset during the first and second cropping seasons, respectively.

Late blight disease progress was fitted with a logistic function using chronological days, from the date of planting as a descriptor variable. The estimated rate of disease increase was higher for cvs. NAKPOT4 and NAKPOT5 (moderately resistant) than Victoria (susceptible) contrary to expectation. However, this occurred at a high point of inflexion of the disease progress curve for

these cultivars with high levels of late blight resistance. Such rates of disease increase were therefore obtained later in the growth cycle and probably had little or no effect on gross tuber yield. The delay of late blight onset, mainly among early-planted potato and a rapid growth to the peak of the disease progress curve is suggests that these cultivars may possess major gene resistance to late blight. The point of inflexion, final disease severity and relative area under disease progress curve (rAUDPC) were consistent in describe difference among cultivars for late blight resistance than the commonly used rate of disease increase.

Assessment of the relationship between rAUDPC and other disease progress parameters indicated a low and negative correlation between rAUDPC and rate of disease increase ($r = -0.182$), or point of inflexion ($r = -0.481$). High and positive correlation coefficients were obtained between days from planting to late blight onset and the point of inflexion ($r = 0.822$), final disease severity and upper asymptote ($r = 0.864$) and final disease severity with rAUDPC ($r = 0.816$). The inflexion point (Y_M) was related to the number of days from planting to disease onset (x) by a linear function as $Y_M = 1.26x + 11.49$ ($R^2 = 88.9\%$).

Analysis of test factors influencing overall disease severity indicated that the difference in rAUDPC were due to the main effects of planting date and potato cultivar and not their interaction. The rAUDPC was highest among late- than early-planted second cropping season potato. During the first cropping season, the rAUDPC progressively decreased with delay in potato planting. The rAUDPC was consistently higher for cv. Victoria than NAKPOT4 and NAKPOT5 across seasons over all planting dates.

Fungicide spray schedule options indicated a 23-28 days delay in disease onset with weekly Agro-zeb 80 WP (mancozeb) sprays after late blight had been detected among non-fungicide sprayed, early (1st March or 1st September) - planted potato. However, the delay in disease onset between fungicide sprayed and unsprayed potato decreased with delayed in potato planting. Among late-season planted potato, late blight occasionally appeared first in fungicide-sprayed than unsprayed potato.

Among early-planted (1st Mar. or 1st Sept.) potato, a single initial spray with Agro-zeb spray prevented late blight onset for 5-6 more days after the disease had appeared in unsprayed potato. This contrasted with 18-20 days protection with a systemic fungicide as a single initial fungicide treatment. It took 13-14 days for late blight to increase from 2-5% severity among early- cropping season planted potato that had initially received one protectant fungicide spray. Subsequent growth in disease severity was rapid and it took less than 4 days for disease to increase from 6 to 25% especially among late-planted potato in a cropping season.

Fungicide spray options, as test components for developing integrated late blight management technology befitting continuous potato planting indicated that no more than three fungicide sprays were required for cost-effective late blight management. This included one spray with a systemic fungicide in a crop cycle not exceeding 100 days even in severe epidemics that were studied. This however was possible by following an action threshold approach integrating protectant and systemic fungicide in the spray program. Data showed that, potato planted at or before 1st September can be grown without fungicides. The study further revealed that 1st March is not early enough to avoid fungicide use in potato production. In these and late-planted second cropping season potato, late blight appeared soon after crop emergence. The first spray against late blight should be preferably made with a systemic fungicide.

Comparisons of rAUDPC among fungicide spray options indicated that fixed-interval sprays significantly ($P \leq 0.05$) differed from action threshold-based treatments but not in total tuber yield ($t\ ha^{-1}$). As expected fungicide sprayed potato had significantly ($P \leq 0.05$) lower rAUDPC and higher yields than unsprayed potato. There were significant ($P \leq 0.05$) differences among action threshold treatments in rAUDPC but not total tuber yield indicating that the observed differences in disease severity were not high enough to proportionately affect total tuber yield. Therefore, optimal yields are not necessarily obtained in total disease absence. Economic analysis further revealed that weekly protectant and 25-day interval systemic fungicide sprays are not profitable. The highest marginal rate of return (MRR) was obtained among action threshold-based treatments but when intervention in protectant fungicide spray programme with a systemic fungicide was made before disease severity exceeded 15%. Interventions made at higher action thresholds progressively reduced profitability probably because the systemic fungicide was not able to stop disease progress or action was taken too late when the crop had already suffered irreparable damage.

Multiple linear regression analysis indicated that the rate of yield loss was a function of late blight severity as rAUDPC, independent of potato cultivars, but highly influenced by cropping season and planting date. Assessment of procedure for generating disease severity for computing AUDPC for yield loss modelling indicated that the multiple fungicide treatment procedure was superior to cultivar resistance differences. The model relating tuber yield to rAUDPC was best fitted as independent equations for planting dates per season having separate y-intercepts and gradients. The model accounted for more than 90% of the observed variation in predicted yield. Model gradients indicated that the rate of yield loss was higher during the second than first cropping season and increased with delay in planting. It ranged from 70-320 and 310-410 Kg ha^{-1} rAUDPC^{-1} during the first and second cropping seasons, respectively. The separate y-intercepts indicate that in theoretical absence of late blight, the second cropping season has a higher yield potential than first season under optimal, rain-fed potato growing conditions in the highlands of south western Uganda.

Generating disease data for yield loss modelling for integral models such as rAUDPC can be difficult and costly. However, data showed that the rAUDPC can be estimated from final late blight severity (%) recorded towards crop maturity at the peak of tuber bulking without need for several, season-long disease assessments. The models relating rAUDPC to final late blight severity were highly significant ($P<0.001$) and accounted for more than 90% of the observed variability. Thus, yield and yield loss can be indirectly and cheaply determined from final late blight severity through the rAUDPC-final disease severity sub-model feeding into the rAUDPC-yield model. Empirically, yield loss ranged between 13 and 57%, being lowest during early-planted second cropping season and highest among late-planted first season potato.

From this study, late blight onset in the highlands of S.W. Uganda can be predicted from accumulated hours with RH≥90% and accumulated rain days but both computed from either 1st March or 1st September, as reference planting dates, due to onset of seasonal rains in multiple linear regression modelling. Seasons and planting date were included as qualitative factor variables. The point of inflexion of the disease progress curve was linearly related to days from potato planting to late blight onset. The rate of disease increase was not consistently related to other disease progress curve parameters as cultivar late blight resistance descriptors. Basing on these data, late blight in S.W. Uganda appears earlier during the first than second cropping season but overall disease severity is higher during the second than first season. The rAUDPC decreased with delay in potato planting during the first cropping season and increased during the second season. The difference in disease onset among varieties did not exceed six days, appearing at the same time among cultivars in late season-planted potato and sometimes earlier among fungicide sprayed than unsprayed potato.

Weekly protectant and 25-day interval systemic fungicide sprays were found unnecessary for cost-effective late blight control in this study. Late blight was profitably controlled in action threshold approach integrating protectant and systemic fungicides as long as the later was used before the severity exceeded 15%. This approach resulted appreciable disease control with reduced fungicide use, high yields, increased returns and had no influence on the incidence of tuber late blight infection. Data further revealed that potato planted by 1st September did not require fungicide spray but not the potato planted by first March as a disease escape strategy. Models for predicting late blight onset and, yield and yield loss explained >80% of the observed variation in the relevant variables however, they were not validated in this study. Future studies would consider validation of these models and include tuber latent late blight infection, variation in inoculum loads and *P. infestans* race composition over a cropping season at influencing late blight epidemic development and progress in continuous potato planting commonly practiced tropical highlands.