Soybean Trials under Smallholder and Large-Scale Farming System

For

Palladium Group

Investigating the optimal plant population of Soybean Maksoy 3N variety in Northern Uganda in the context of previous agronomy trials

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1. Overview

Based on the first season trials conducted which investigated different input packages for Soybean, it was observed that there was a noticeable difference between soybean plants vigor in the center of the trial blocks, and those within the block. We have had two experienced largescale commercial farmers visit the trials as well as Palladium team members who supported these observations. The plants on the boundaries were noticeably more vigorous and showed less signs of hydric stress. This would indicate that there was more soil moisture and competition for light within the blocks, and that perhaps the seeding rate of 300 000 plants per Ha was not ideal above the optimal plant population. It may be having a negative effect on yields. Under local conditions, the guidelines for soybean cultivation have been particularly vague on plant population. Therefore, based on these observations, a second trial was initiated to determine the optimum plant population for soybeans under our local conditions.

Seed is an expensive input costs for soybean growers, so it's important for growers to plant the right number of seed to minimize input costs and increase profitability. Seeding rate, plant population, and row spacing are tied together. If the population is too high, plants compete and often lodge. If the population is too low, a producer is wasting growing space and lowering yield. Low populations also result in increased weed pressure. As row spacing increases, the optimal number of plants per acre decreases.

2. Objective

The proposed Trial aims to investigate the relationship between soybean seeding row spacing and plant population and recommend seeding rates and plant populations for various crop row widths. Furthermore, it will evaluate the marginal rate of return between high and low input systems applied across the different row spacing.

3. Background

a. Plant Populations and Seeding Rates for Soybeans

Physiological Response to Plant Population; High plant populations can have some advantages: canopy closure is quicker, light interception is greater, and weed competition is lower. However, yield does not always increase as plant population increases. As the number of plants per hectare increases, each plant captures less light, which limits each plant's growth. High plant populations also increase competition for nutrients and water, may promote lodging, and add to seed costs.
Soybean plants are adaptable. When plant populations are low, individual soybean plants increase their leaf areas — which allows each plant to capture more sunlight — and produce more branches — which allows each plant to produce more pods. This characteristic (called plasticity) means that low soybean plant populations can offer competitive yields. This was observed to some extent on plants that were on the border of trial blocks in the trials established in April 2017. However overall, It was noted that Maksoy 3N is a variety that is limited in its ability to do this. On wider row spacings it was noted that the plants did not fully occupy the inter row area.

4. Determining Optimum Plant population and row spacing for Maksoy 3N

Many factors influence plant population and seeding rate, including row spacing, seed placement and planter calibration, and the seed's germination rate.

Factors Driving Row Spacing Trends

a. **Equipment**

Other than yield, the most important factor driving soybean row spacing practices is equipment. One of the key issues growers must consider is whether the economics of their farm justify having a machine dedicated specifically to planting soybeans. Larger farms are more able to justify the expense of a dedicated soybean planter. Thus, they are more likely to be able to plant soybeans on 38cm or 19cm rows. For smaller farms, it may be more practical to share a soybean planter with another crop, such as a 75cm planter for maize. This often results in more small farmers using 75cm row spacing's.

As farms get larger, more area must be planted in a shorter amount of time. To plant more area during the available window, some growers have opted to use their 75cm planter for soybeans. Because 75cm planters are typically wider than 40cm planters, they can cover the ground more quickly. Another option – owning a second planter specifically for soybeans – allows both crops to be planted at the same time, resulting in earlier completion of soybean planting. However, the total number of operator hours spent planting would be greater. It is difficult to weigh the potential yield benefit of narrow-row soybeans against equipment costs, time constraints and operator availability required.

Soybean planted in Nwoya district with maize planter on 75cm spacing (2016)

Equipment and workload considerations are unique for every farm operation and ultimately come down to the needs of each individual grower. But being informed with accurate data on the yields under different spacing will allow farmers to make good decisions. For this reason, we have tested three row spacing's and different plant populations.

b. **Foliar Fungicide and Insecticide Applications**

The need for fungicide and/or insecticide applications may also impact row spacing decisions. When an application is made during vegetative growth, plants are generally able to compensate for damage caused by the sprayer wheels with little reduction in yield. For applications made following the R1 growth stage, which would include most foliar fungicide and insecticide applications, wheel damaged areas will have lower yield. A research study conducted in Delaware and Virginia found significant yield reductions due to sprayer wheel damage in R4 soybeans planted in 19cm and 38cm row spacings, whereas soybeans planted in 75cm and wider row spacings did not sustain any sprayer wheel damage (Holshouser and Taylor, 2008). Actual yield loss due to wheel traffic will vary according to boom width.

c. ***Weed Control***

It is becoming increasingly necessary to consider the impact of cropping system factors such as row spacing on weed growth. In general, weed growth will be reduced in soybeans planted in narrower row spacings and earlier shading by the soybean canopy will help suppress the emergence of new weeds. The extent of this effect will vary by weed species and weed emergence timing relative to the crop (Hock et al., 2006).

Soybeans at low and high [redacted] showing difference in weed competition (Northern Uganda).

d. ***Planting and Harvest Efficiency***

Crop residue can be an important consideration when planting soybeans. Some growers in high residue systems prefer wider rows because there is more room to deposit residue between the rows, which helps prevent residue interference with planting and emergence.

Narrow-row soybeans offer some harvestability advantages over soybeans in 75cm rows. The lowest pods will tend to be higher in narrow-row soybeans, potentially reducing harvest losses. The more even distribution of plants in narrow rows also allows plants to feed into the combine head more smoothly, although some growers have found that harvesting 75cm row soybeans at an angle can help improve harvestability.

That said recent research studies have shown many different considerations beyond simply yield potential can affect the best practices for each individual grower. Factors such as equipment costs, workload management, and disease management all play an important role. When those issues are accounted for, narrow-row planting is not necessarily the best economic choice for all operations. Because of this complexity, no one-size-fits-all answer should be applied. Rather, each grower should carefully consider the costs, risks and benefits of soybean row spacing options in their operation.

5. Materials and Methods

It's generally accepted that plant populations for soy can range from 150 000 to 350 000 plants per ha. Based on these industry norms, and field observations, combined with current practices and the type of equipment in Uganda, three row spacing's of 75cm, 38cm and 19cm have been selected. Within these row spacing's 3 different intra row spacings were selected. These are reflected in the table 5.1 below.

Table 5.1 Plant Population Treatments

Plant population/ha		inter row spacing (cm)		
		75	38	19
intra row spacing (cm)	6,00	222 222		
	7,50	177 778	350 877	
	9,00	148 148	292 398	
	12,00		219 298	
	14,00			375 940
	16,00			328 947
	19,00			277 008

The trial was replicated over two sites in Amuru and Nwoya District. A randomized block design was used. Each plot measured 5 x 10m. There was a total of 8 replicates for each treatment at each site. Basal fertilizers were incorporated using a rotovator. Knapsack sprayers were used for applying crop protection products at one location and a self-propelled boom sprayer was used at the other.

Table 5.2. Input Treatments

Inputs	**low input**		**Hi Input**	
	rate/ha (kg or L)	**no of applications**	**rate/ha (kg or L)**	**no of applications**
Seed Treatment				
Rhizobium japonicum	as indicated	1	as indicated	1
Trichoderma	as indicated	1	as indicated	1
Fertilizer				
calcipril	100	1	200	1
TSP Basal	150	1	300	1
SOP Basal	100	1	200	1
Solu potasse (42% K and 18% S)	2% solution	1	4% solution	2
Yara Vita Tracel Bz NPK+Trace E. Cocktail	5			2
Insecticides				
Match	0,5	1	0,5	1
Avaunt	0,25	1	0,25	1
tracer	0,2	1	0,2	1
Fungicides				
Acanto plus 380sc	0,3	1	0,3	2
Herbicide				
Pre planting Glyphosate	4	1	4	1
Post emergence Basagran	2,5	1	5	2
Post emergence Fusilade	1	1	1	1
Hand weeding		1		1

The seed variety used was Maksoy 3N. The plots were planted by hand using a string and markers for accuracy. Planting depth was 20-30mm. Seed was inoculated with rhizobium and Trichoderma at the time of planting at rates recommended on the label. The trials were sprayed as and when needed to keep pests below threshold levels. See table 5.2 for more details.

Data Analysis. On harvesting the soybeans, it had become evident that the theoretical plant population that were targeted for the trials different treatments were not achieved for several reasons including soil erosion, seed viability and pest attack. As a result of this we decided to take a different approach to analyzing the data. Rather than divide the data into treatments based on the theoretical plant populations, the actual plant populations for the three different rows spacing, 75cm, 38cm and 19 cm respectively were used. The challenge on this trial was a higher degree of experimental error introduced with higher-than-expected levels of variation across the trials site. Early in the season this was not evident, but as the soils started to dry out in the second part of November, these variations became more evident. The actual plant populations were determined from plant counts in each field plot. The following methodology was used to analyze the data

a) Generate the scatter plots to assess the fit and spread of data

b) Generate and compare the correlation coefficients

c) Run linear regression analysis

d) Run non-linear regression analysis following a quadratic equation

e) Predict fitted values of yield based on the quadratic model

f) Plot the graph of fitted values against the plant population

6. Results and discussion

a. The scatter plots showed significant variation in yield versus plant population, and the gradient of the fitted lines showed a seemingly low correlation. Variation was greater on wider row spacing's than narrower row spacing's. And the narrower row spacing of 19cm had higher yields overall. It can be concluded that the narrower row spacing is more suitable because the results are more reliable, and the yields are higher.

Figure 6.1 shows the scatter plot for the populations across the 75 cm row spacing treatments. It is observed that the R^2 value (0.11) also suggested a low explanatory power of the variation in yield attributed to plant population. The highest yield recorded was 1980kg/ha at a plant population of 133 000 plants per Ha. The trend was as expected with the lower plant populations having lower yields. But overall and compared to the other row spacing's of 38 and 19cm, the widest spacing (as used in maize) is not suited to soybean. Field observations revealed that at least 50% of the space between the inter rows was not use. And as expected there was a higher level of weed pressure.

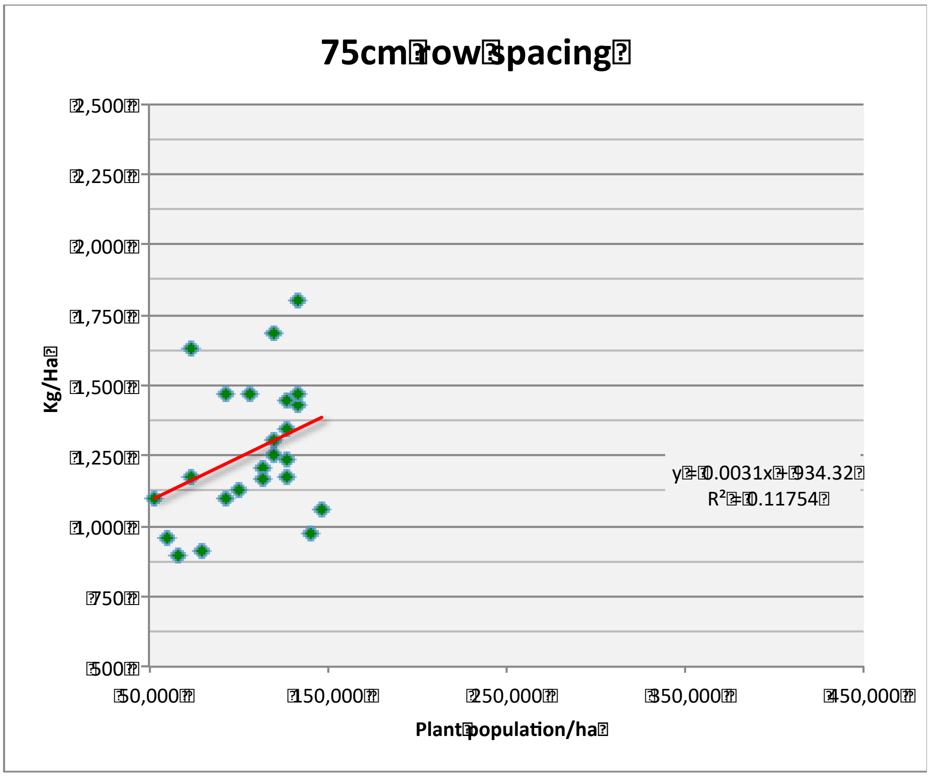


Figure 6.1 : Yield for different plant populations on 75cm row spacing

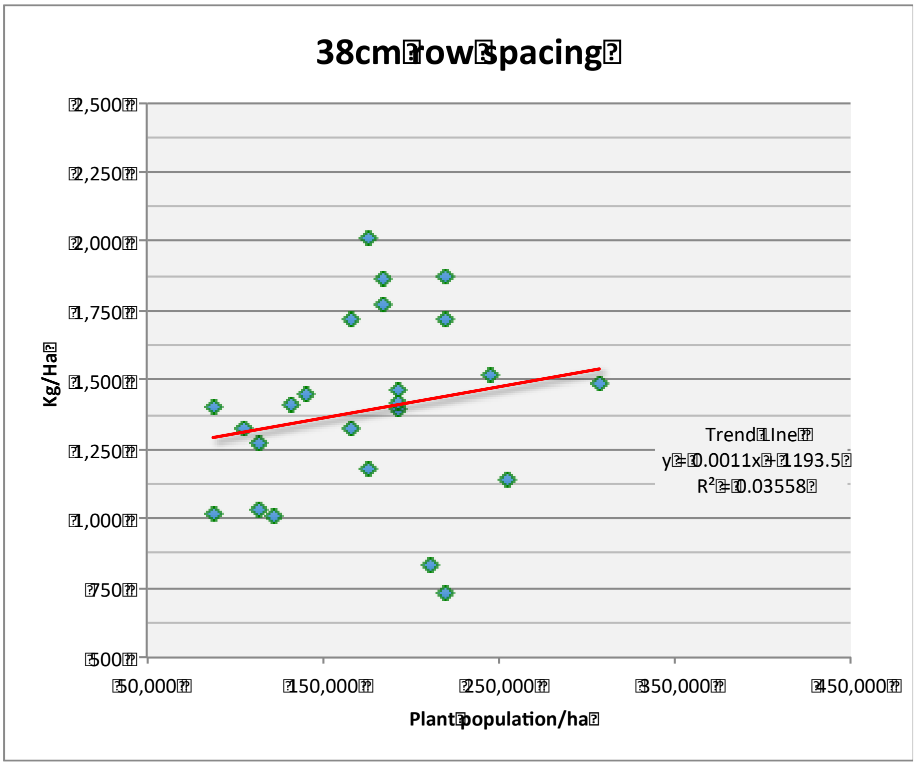


Figure 6.2: Yield for different plant populations on 38cm row spacing

Figure 6.2 shows the scatter plot for 38 cm row spacing. It is shown that the scatter points and the best line of fit also suggested a very low correlation and the assertion is corroborated by the significantly low R^2 value. Highest yields were achieved on populations between 160 000 – 220 000 plants per ha. The results in the graphs do reflect that yields can be very low at these spacing's too, but the low values on these out liars should be seen in context. These values may be attributed to adverse field conditions at the trial plots. It was realized subsequent to the trials that some spots had very shallow ground and poor internal drainage.

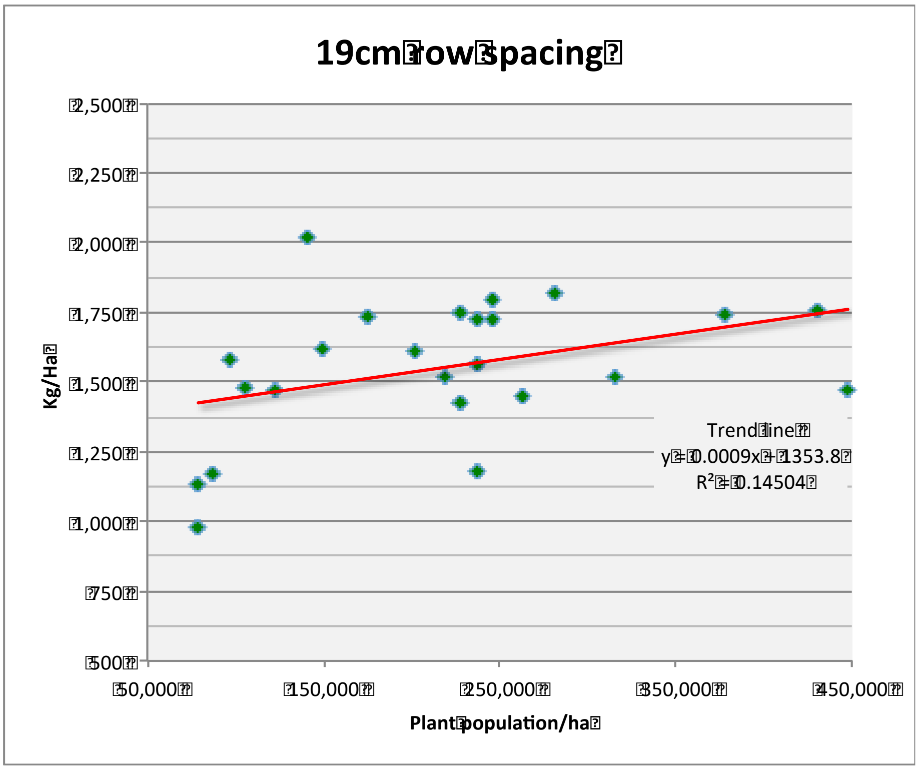


Figure 6.3 : Yield for different plant populations on 19cm row spacing

Figure 6.3 shows the scatter plot for 19cm row spacing. The results showed that compared to the other two preceding scatter plots, more scatter points are closer to the best line of fit and the gradient of the line is higher as is the R^2 value. Consistently higher than average yields were obtained with plant populations above 240 000 thousand and below 370 000 plants per ha. Although interestingly the highest yield of 2.2 tons per ha was achieved with a plant population of 140 000 plants per ha. This shows the potential under ideal conditions, but again this was an outlier

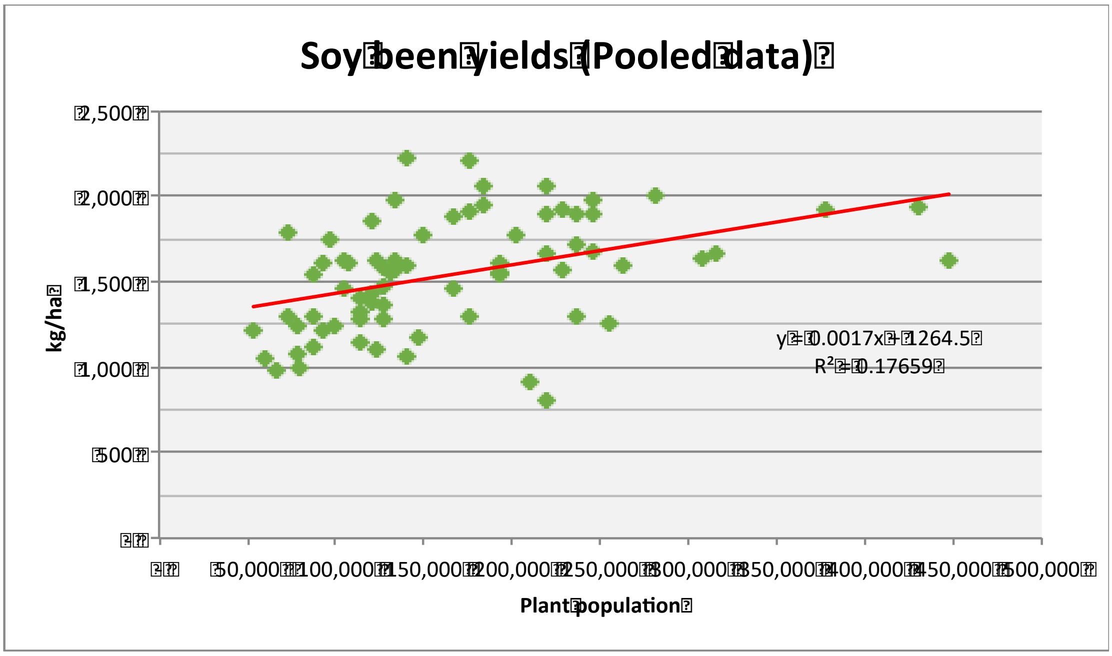


Figure 6.4: Pooled data for plant populations and correlating yields

Robust correlations and causality regressions using STATA
The correlations are shown to be weaker for populations under 75 and 38cm row-spacing's in relation to 19 cm row spacings. There is a higher degree of correlation for the pooled data as expressed from the R^2 value (0.17) Figure 6.4.

Table 1: Correlations

Row spacing	Correlation coef.	Description of the correlation between yield and plant population
Pooled	0.408	Fair strong
19 cm	0.381	Weak
75 cm	0.344	Weaker
38 cm	0.189	Weakest

The results showed the coefficient for the pooled data and the population at 19 cm are significant at 1% and 10% respectively whereas the others are not. Similarly, the R2 values are higher for pooled data and plant populations at row spacing 19 cm. In the model for 75cm and 38cm row spacings, the data does not fit the model

Table 2: Regression equations

Variable	Constant	Regression coef.	Prob>t	Prob> F	R2
Pooled data	1279.29 (81.118)	0.002	0.000	0.0004	0.166
Population 19	1489.14 (124.466)	0.001	0.066	0.0664	0.145
Population 75	1027.75 (219.044)	0.003	0.101	0.1010	0.118

Population 38	1312.80 (253.131)	0.001	0.377	0.3774	0.036

Note: the t-values test the fitness of coefficients whereas the f-test is for the overall model fitness

The correlations and regressions thus informed the choice of the linear regression models to be further analyzed. The table below shows the transformed linear equation 1 to non-linear equation 2 to cater for eventual drop in yield as would be eventually expected from interplant competition.

Eq. 1 $y = \beta_0 + \beta_1 x_1 + \varepsilon$
Eq. 2 $y = \beta_0 + \beta_1 x_1 + \beta_2 x_2^2 + \mu$

Table x and x show the non-linear regression models for non-pooled data and pooled data. Based on the R2 and the MSE, we selected the non-pooled data as a better predictor of yield.

Non-pooled data

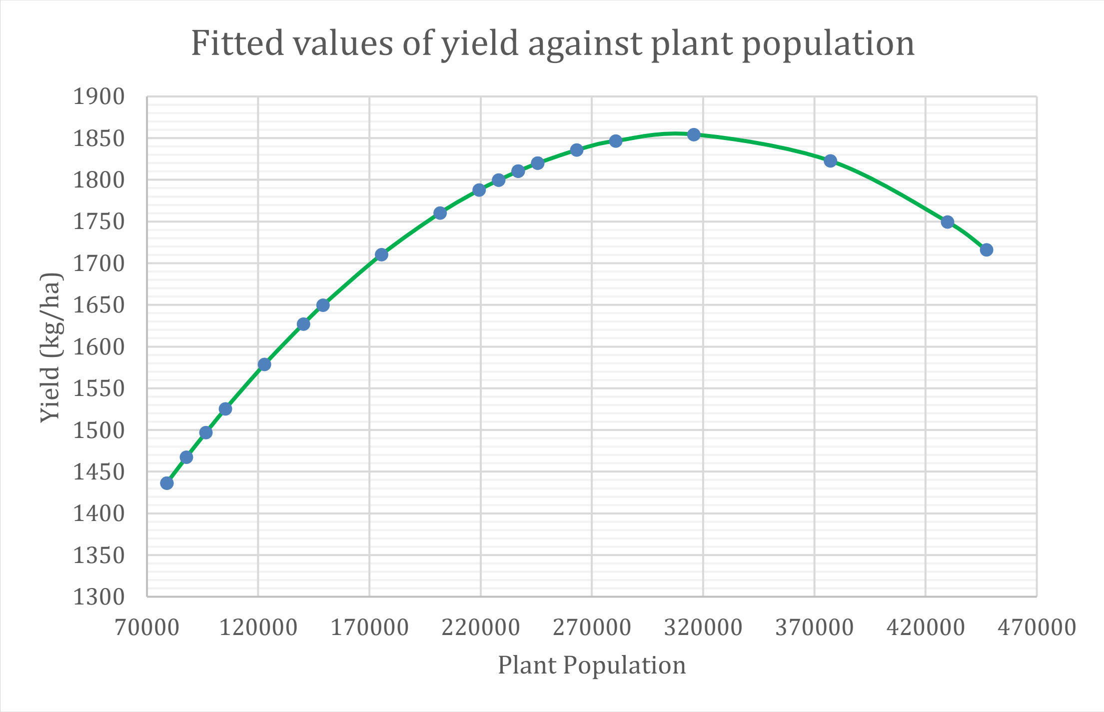
Variable	Regression coef.	Standard error	Prob>t
Population19	0.005	0.0019	0.022
Population19_sq	$-9.65*10^{9}$	$3.52*10^{9}$	0.040
Constant	1106.49	239.97	0.000
Observations	24		
Prob>F	0.0433		
R2	0.273		
Root MSE	242.61		

Pooled data

Variable	Regression coef.	Standard error	Prob>t
Population19	0.0046	0.0016	0.005
Population19_sq	$-6.81*10^{9}$	$3.52*10^{9}$	0.057
Constant	1014.731	158.028	0.000
Observations	71		
Prob>F	0.0003		
R2	0.2098		
Root MSE	293.05		

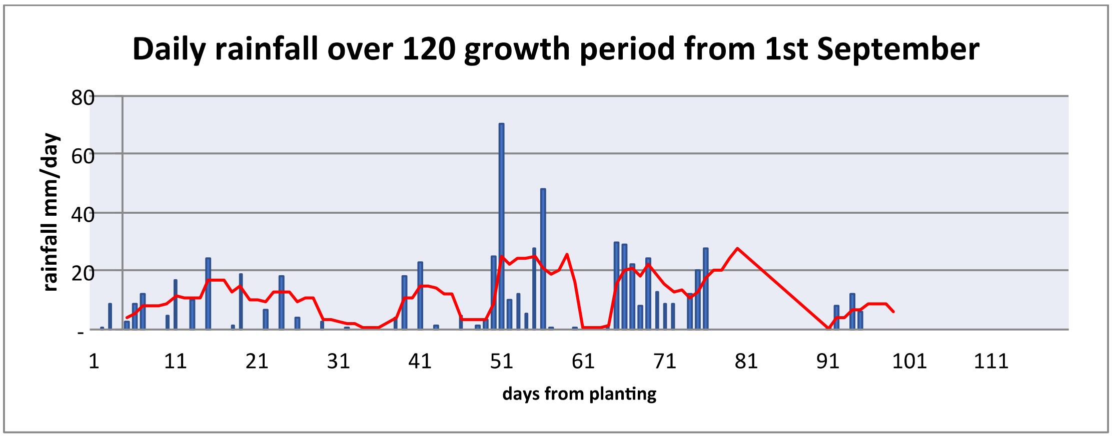
Based on eq.2 and using non-pooled data, fitted values of yield were generated and the graph below shows a plot of yield against the plant population.
The graph shows that as plant population increases, yield increase but to a point where a maximum is attained and thereafter, the yield starts to drop as the plant population increases. From this trial it is shown that maximum yield can be achieved within a range of 270,000 – 320,000 plants per ha. From the trial results [redacted] It should however be noted that this is not the maximum yield obtainable. And we can expect to hit the 2500kg/ha mark with planting on time and a suitable input package.

Of interest is that this treatment had the lowest number of pods per plant with an average of 87 pods per plant, but this was set off by the high population. The highest number of pods was achieved with the 75cm row spacing with 140 pods per plant. These results were consistent across both trial locations.



b. General discussion on the seasons growing conditions

Total rainfall received over the growing period was 631mm, but 95% of the rainfall was received in the first two thirds of the growing season. The soils are sand loams with an effective profile depth of 450-500mm and have a relatively low water holding capacity. Experience in this area shows that most crops typically start to show signs of water stress after 10 days without rainfall during the warm summer. There is no doubt that the inadequate rain and soil moisture would have had a significant effect on the final yield of this crop. From day 95 through to 120 there was no rain. This was during pod fill and a critical period for the plants. It was estimated that the slightly late planting dates for the trials and the rains tailing off two weeks earlier than expected in the second half of November significantly impacted the yields that were achieved. This impact of water deficit was evident from data collected on the level of aborted seeds and pods.



Pod counts revealed that 19% of the pods had been aborted between the 10th of October (R6) and the 18th of November (R8). But further to this, it was observed that with in the pods retained on the plants, out of this 40% of the seed produced was shriveled and not suitable for planting. This would serve to indicate that had the trials been planted 4 weeks earlier and received rainfall throughout the pod filling stage , the yields would have been at least 35% higher than what was realized. This would suggest that yields of 2,5ton/ha are attainable when planting earlier in the season. Timing of planting is critical for soybeans.

Annex 1
Recommendations based on the last two seasons trials

c. Where to plant
   i. Soybeans need to have a well-prepared seed bed. It is common practice amongst small holder farmers to only plow the field once or twice. But it is advisable to go over the soil with a disk harrow. This has shown to give better results.
   ii. The fields should be well prepared ahead of the set planting date. If old land or new virgin areas are being planted, be sure to allow enough time for the decomposition of crop residues and other organic material. High levels of undecomposed organic matter have a negative impact on yields. Soybean is not suited to being the first crop in newly opened fields, avoid this if possible. If not expect a 20-25% reduction in yields for the first season.
   iii. In old lands that have been plowed for several seasons it is advisable to break through the plow pan with subsoiler. The root system is sensitive to compaction, and a plow pan will reduce yields.
   iv. Be aware of fields that may be carrying residual levels of the herbicide atrazine, this will have an impact on your yields.

d. When to plant
   i. 1st season and second season timings. In Northern Uganda, Macksoy 3N requires a growing season of 120 days. Planting should commence after the rain season has started and the soil profile is moist. Dry planting is not advisable with soybeans.
   ii. Study the historical rainfall patterns and aim to start about 2 weeks after the season is under way.

e. How to plant
   i. Preparing the seed bed.
      Ensure the seed bed is free from weeds. There are two ways to rid the field of weeds. Mechanically with a light disc or tined cultivator. Or chemically using a non-selective herbicide such as paraquat or glyphosate.
   ii. Seeding depth.
      Plant between 20-30mm depth. Ensure the soil is loose and friable. If the soil becomes capped after planting due to rainfall and sunny conditions, use a very light tined implement or rake to loosen the soil above the seed. Heavily capped soils can affect the emergence of soybeans. This has been observed on soils in northern Uganda. Applying a light mulch over the soil surface will also help. Use grass cuttings or rice husks. This will also help prevent burn on the hypocotyl at emergence.
   iii. Inoculation
      Soya bean seed must be inoculated at planting. Do not plan without inoculating. Inoculate the seed the same day that you plant. Only inoculate enough seed for the day on which you will plant.

iv. Plant spacing and plant population

Planting on an 19cm row is most preferable. If this is not possible then keep to a 38cm row. It is not advisable to plant on a 75cm row spacing. Target a population of 280 000 - 320 000 plants per ha. In practice this results in an in line spacing of 18,7 to 16.5 cm plant to plant on the 19cm row spacing. Before planting establish the viability of the seed and adjust the seeding rate to compensate accordingly.

f. Fertilizers

i. Before applying fertilizers, have your soils analyzed to determine which elements are most limiting. In northern Uganda where the trials were conducted, it was found that Boron and Sulphur were severely lacking and this required rectification.

ii. Based on trials results and field observations the following guidelines are given.

Table 1 Fertilizers

Timing	Fertilizer	Application	Amount
Pre plant	Phosphate (TSP)	Off set Band at low volumes, spread at higher volumes	45-90kgP_2O_5 *
	Lime	Incorperate	500-2000kg/ha depending on pH
At planting	Potassium	Band application on planting line	20-25K_2O**
Top dressing 1 At flowering	Potassium, Sulphur,	Foliar	5-10kg of SOP
	Boron***	Foliar	5kg Solubor
	Micro nutrients****	Foliar	as per label
Top dressing 2 At onset of pod filling	Potassium, sulpher Boron	Foliar	5-10kg of SOP
	Micro nutrients	Foliar	5Kg Solubor
		Foliar	as per label

*Note that soils with a P content of 20-30ppm (Bray1) would be regarded as optimal.
** The response to K fertilizers is unlikely on soil test levels above 120ppm
*** Soils in Northern Uganda are deficient in Boron
**** Should not contain high levels of Nitrogen

g. Plant protection

i. Herbicides

Keeping the field free from weeds is essential. A product with active ingredients Quizalofop-p-ethyl 35 gr/lt and Fomesafen 125 gr/lt proved to be most effective for post emergence control of weeds. Products with the active ingredients FLUAZIFOP-P can also be used for the post emergent control of grass species at an early stage, as can bendioxide (thiadiazine) for the control of broad leaf weeds. Common trade names of these and other useful herbicides are

- Mofano 160ec
- Fusilade forter 128 ec

- Basagran

ii. Fungicides

Soybeans are susceptible to rust during high humidity and high rainfall periods. Active ingredients of the triazole and strobilurins, group 3 and 11 have proved effective. Common trade names of these herbicides are

- Nativo
- Folicure
- Score 250ec

iii. Insecticides

Most common threat will be Lepidoptera and Spodoptera (FAW) species and stink bugs. For these species especially army worm, spray at the first sign and when larvae are small.

Stink bugs will feed on the flowers and bods. The economic thresh hold for stink bud is in the region of 1-3 bugs per foot along the row. If you see more than this, then you must spray. Routine scouting of the fields is necessary to determine the economic threshold. For Lepidoptera and Spodoptera the following active ingredients and products have proven to be effective when sprayed correctly and on time (table 2) and were used in the trials. Termites may also cause problems in some areas, particularly during dry periods.

Table 2 Insecticides

Target	Insecticide	Active Ingredient	Group
Lepidoptera and Spodoptera (FAW)	Tihan	Flubendiamid+ Spirotetramat	28+23
Lepidoptera and Spodoptera (FAW)	Avaunt	Indoxacarb	22a
Lepidoptera and Spodoptera (FAW) Stink Bugs	Karate	lambda-cyhalothrin (pyrethroid	3a
Lepidoptera and Spodoptera (FAW) Stink Bugs		Alpha cypermethrin	3a
Termites	Regent	Fipronil	2a

iv. Harvesting

Under certain circumstance harvesting will take place during wet periods and the soybean plants will require defoliation to assist with harvest.

Annex 2 Crop Costing and Gross Margin

When combining the lessons learnt from the two sets of trials in 2017, we can conclude that the following scenario would be highly likely. With plant population of 280 000 – 320 000 thousand plants per Ha, suitable plant timing, adequate field preparation and good rains, combined with the following input package, soy could yield between 2000-2500kg per ha and return a gross margin of 44% based on a price $400/ton.

Tractor Hire	
Plough	240,000
Disc	180,000
Manual Labour	
Planting	80,000
Harvesting	100,000
weeding	240,000
Seed & Seed treatments	
Seed cost	315,000
Rhizobium	94,500
Trichoderma	140,000
Fertilizers & Nutrition	
TSP	175,200
K leaf	110,000
green grow	40,000
Insecticides	
Avaunt	109,500
lambdastar	19,500
Movento	45,000
Herbicides	
Strim	48,000
Mofarno	91,250
glypohosinate	165,000
Total Cost	**2,192,950**
Mean Yield	**2,250**
Revenue	**3,150,000**
Gross Profit mean yield	**957,050**
Return on Investment	**44%**

References

Cox, W.J., and J.H. Cherney. 2011. Growth and yield responses of soybean to row spacing and seeding rate. Agron. J. 103:123-128.

De Bruin, J.L., and P. Pedersen. 2008. Effect of row spacing and seed- ing rate on soybean yield. Agron. J. 100:704-710.

Hanna, S.O., S.P. Conley, G.E. Shaner, J.B. Santini. 2008. Fungicide application timing and row spacing effect on soybean canopy penetration and grain yield. Agron. J. 100:1488-1492.

Hock. S.M., S.Z. Knezevic, A.R. Martin, and J.L. Lindquist. 2006. Soy- bean row spacing and weed emergence time influence weed competitive- ness and competitive indices. Weed Science. 54:38-46.

Holshouser, D.L., R.D. Grisso, Jr., and R.M Pitman. 2006. Uniform stand and narrow rows are needed for higher double-crop soybean yield. Online. Crop Management doi:10.1094/CM-2006-0417-01-RS.

Holshouser, D.L., and R.D. Taylor. 2008. Wheel traffic to narrow-row reproductive-stage soybean lowers yield. Online. Crop Management. doi:10.1094/CM-2008-0317-02-RS.

Janovicek, K.J., W. Deen, and T.J. Vyn. 2006. Soybean response to zone tillage, twin-row planting, and row spacing. Agron. J. 98:800-807.

Kratchovil, R.J., J.T. Pearce, and M.R. Harrison, Jr. 2004. Row-spacing and seeding rate effects on glyphosate-resistant soybean for Mid- Atlantic production systems. Agron. J. 96:1029-1038.

Lee. C.D., K.A. Renner, D. Penner, R. Hammerschmidt, and J.D. Kelly. 2005. Glyphosate-resistant soybean management system effect on Sclerotinia stem rot. Weed Technol. 19:580-588.

Pedersen, P. 2008. Row spacing in soybean. Department of Agronomy. Iowa State University, Extension. http://extension.agron.iastate.edu/soybean/documents/RowSpacing.pdf

Pedersen, P., and J.G. Lauer. 2003. Corn and soybean response to rotation sequence, row spacing, and tillage system. Agron. J. 95:965-971.

USDA-NASS Objective Yield Surveys http://www.nass.usda.gov/

https://www.pioneer.com/home/site/us/agronomy/crop-management/soybean-insect-disease/green-stink-bug/#Management