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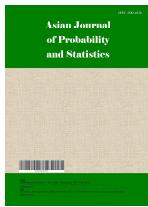
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Assessment of French Beans Production at Kariua in Kandara, Murang'a County- Kenya

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Authors' contributions

This work was carried out in collaboration among all authors. Authors AO and AA developed the idea, designed the study, wrote the protocol and proofread the first draft. Author WPM managed the literature searches, performed the statistical analysis and wrote the first draft of the manuscript. All authors read and approved the final manuscript.

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Abstract

A sample survey research was conducted in November 2017 to January 2018 at Kariua area in Murang'a county, Kenya, with a sole aim to assess the current situation experienced by the French bean farmers in the area as well as form basis for further research, in which 43 farmers were interviewed. The parameters of interest were the average input levels of various factors (*manure, fertilizers and water*), average *spacing of the crops* in the field, the average *output of the beans*, the general *plants' health*- all these were per crop point, *land sizes* under French beans cultivation as well as the *demographic factors* like *age, gender* and *family size*. The questionnaire was the main data collecting tool. Analysis of the data collected was carried out using both descriptive and inferential statistics: Using both R software and Ms-Excel. The results showed that farmers are experiencing very low yields at peak on average and poor plant health (*harvest=13.4 g, infected leaves= 8 and immature pods= 15, all per crop point*). Average *land size* under French beans farming, *D.A.P* and *C.A.N* fertilizers applied, *manures* applied, *crop spacing* and *water* for irrigation were found to be approximately 79.80 m^2 , 4.75 decigrams, 2.49 decigrams, 24.69 grams, 9.81 cm by 27 cm and 4.38 litres respectively. Low yields and poor crop health, scarce resources, pests, infections, diseases and intercropping and were also evident in the region.

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1 Introduction

1.1 French Beans in General

Beans, *Phaseolus vulgaris*, serve as sources of proteins. The world's estimation of the produce is a challenge due to intercrops. Intercrops lower yields and increase area under farming and hence a challenge in over-approximation of the area under the crop's farming and under-assessment of the total output [1]. French bean, *Phaseolus vulgaris* L., is part of legume species. It is widely known as 'common bean' because it is the most generally eaten bean in the world or 'snap bean' due to the sound produced when the green pod is broken. The planting rate is about 150 to 400 thousand of seeds in a hectare and this rate is lower when intercrops are involved. Although the spacing is about 30-90 cm by 15-30 cm for bush-type cultivars and 30-120 cm and 3-6 crops in a given hill for pole type cultivars, the spacing depends on local practices. However, increase in crop density leads to more outputs [1,2].

The cultivation of French beans is thought to have been done in the south and central America and Mexico. India is the leading producer of French beans while in Latin America Caribbean and Africa, the leading nations are Brazil and DRC, Kenya, Tanzania and Uganda respectively. However, the largest consumers are citizens of Burundi, Kenya and Rwanda while the rest of the countries produce much and export much [3]. Small-scale French bean farmers in Kenya comprise approximately 80% of the French bean growers. In area with high production potential such as around Mt. Kenya, the sub-division of land has led to minute landholding. In Kenya, the French bean is a highly significant vegetable in generating incomes through export to, majorly, European countries. High levels of inputs are required with the cultivation taking place in the entire period of the year when there are no heavy rains- the heavy rain seasons are in April to June and October to November [4]. Production in Sub-Saharan nations is very low compared to some developing countries like Asia. For instance, approximately 2.4 to 3.2 tonnes of French beans per acre of land can be reported in Kenya while South America and Asian parts report about 6.1 and 8.1 tonnes from the same land size [5]. In India, approximately 5.5 tonnes per acre of land can be produced [6] while it is about 2.3 tonnes per acre in Greece [7]. The world produces about 5.7 tonnes per acre while China produces about 10.7 tonnes per acre as the world's leading producer [8].

1.2 French Beans at Kariua

The adoption of French beans farming in Kariua sub-location by farmers, and in general, Kandara constituency area in Murang'a, has been at high levels in the recent years due to lack of other means of offering solutions to their money problems. However, poverty levels, pests, diseases and infections and extremely limited resources in the region have dealt a heavy blow in the production. The type of irrigation is manual and those involved in irrigation are of all ages. The farmers boost soil fertility through the addition of inorganic fertilizers such as diammonium phosphate (D.A.P), calcium ammonium nitrate (C.A.N) among other types. According to [9], fertilizers provide soils with nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), zinc (Zn), silicon (Si) among others, and the easiest way to add nutrients to the soils is through use of inorganic types. Some fertilizers are made effective by applying others so that crops benefit from such in the presence of others. This can be explained in the case where salt fertilizers like ammonium sulphate reduce the losses encountered when ammonium is applied in hot days [10]. For these reasons, the farmers at Kariua have to apply different types of fertilizers as well as manures to ensure that the soils' fertility is boosted for better yields.

When it comes to the limited fertilizers provided by the concerned companies, that provide the French bean seeds too, these farmers have to ration it for the sake of other crops in that field such as maize and kales. The limited manure has also to go through intensive rationing. Manpower has been declining with time since most youthful people are schooling in different levels of the academic ladder. Pesticides and other spraying chemicals such as predatory mites, entomopathogenic fungus and others have been discovered and

manufactured with the sole aim of eliminating any pest posing threat to the crops [11] and Kariua farmers apply them in every season. Frequent sprayings not only result in pollution and high costs but also makes the edible pods unfit for human consumption [12]. The bacterial diseases; bacterial blight, halo blight, and bacterial brown spot, have devastating effects on beans in general- making crops in the area to be unhealthy and have low yields.

Indeed, a lot has been done in different aspects when it comes to French beans. Thenmozhi and others have found that the green colour on pods can be improved in terms of retention through lowering the rate of chlorophyll destruction which is the case with many vegetables and potatoes [13]. In the paper by Calvache and others, 1997, the effects of irrigation and nitrogen fertilizers on French beans performance at different stages have been investigated. The experiment showed that the yield from irrigation deficit treatments was lower than those that had supplementary irrigation with flowering stage is the most sensitive to water stress. Nitrogen applied had a positive effect on crops since it increased the number of pods and yields in terms of grains [14].

Meena and Ram, 2018, studied on yield and quality of French bean traits under Lucknow condition. Bio-fertilizers were applied on three varieties of French beans namely; PDR-14(Uday), EC-400445 and IPR-98-3-1. The PDR-14 was found to be better in terms of duration from sowing to first flowering. The types of bio-fertilizers applied were; phosphate, azotobactor, rhizobium, azospirillum and vesicular-arbuscular mycorrhizae. The rhizobium bio-fertilizer was found to be better than the rest since it had better results for yield and quality traits [15]. Petrova and others studied the productivity of the French beans while varying irrigation in Bulgaria. The results showed that the unirrigated areas have improved production during medium wet times of the year from dry times. When the pre-irrigation moisture in soils is maintained between 80-90% of FC, the yield is not only stabilized but also increased [16].

Nazrul and Shaheb found that there is significant variation among the French bean genotypes in terms of yield, with the 5 local genotypes performing better than the 3 developed ones in their research. The Local-4 and Local-5 yielded the maximum output [17]. The research by Ngelenzi, Mwanarusi and Otieno on improving French bean pod yield and their quality was done in 2016 and applied different coloured agro net covers at Egerton University in Kenya. The results were positive since there were more pods on crops, better yields and marketable yields than the control experiments (open field), which means that, netting can help improve French bean production and more so, light-coloured nets [5].

In general, no research has been done at Kariua region in Kandara, to assess what the French bean farmers are experiencing. This sample survey exercise can serve as an eye-opener to researchers in order to investigate on how farmers from the region can be helped in improving their products for better incomes based on the limited resources at their dispensation. It would pave the way for researchers into the next level of research.

2 Methodology

The materials necessary for the experiments were:

- | | |
|---|----------------------------------|
| i) Water and weight measuring instruments | ii) Tape measure |
| iii) Books, pens and calculator | iv) Well-designed Questionnaires |

Both qualitative and quantitative data were collected from the farmers. The computer was used in data management and R software and Ms-Excel were used in analysis. Simple random sampling was used to select subjects for interview where sample size was predetermined. A pilot survey was conducted to test the materials used in which 10 farmers were sampled. The questionnaire was found to have no ambiguity and all the useful information was found to have been captured. However, the question on spacing of the rows in the fields was removed due to uniformity in response: all farmers responded to have spaced their rows at 27 cm.

2.1 Procedures

A sample survey was carried out in Kariua region. The Cochran's formula

$$n = \frac{Z^2 \alpha/2 * P * Q}{d^2} \quad (1)$$

was employed in computing the sample size. In this research, $\alpha = 5\%$ is the level of significance, P = proportion of farmers cultivating French bean crops, $Q = 1 - P$ (proportion of farmers not involved in cultivating French bean crops), Z is the value from standard normal distribution statistical table that corresponds to the specified α - value, d = the margin error and n is the sample size or the number of the farmers sampled. The P was taken to be 0.5 since the actual number of French beans farmers couldn't be determined precisely. The d was fixed to be 0.15 and the formula yielded

$$n = \frac{1.96*1.96*0.5*0.5}{0.15^2} = 42.6844 \cong 43 \text{ farmers.}$$

Based on simple random sampling, data were collected from farmers using questionnaires and interviews. Farmers were observed when at work in their fields as well as questioning them on how they carry out the whole process. The exercise took place from the time of land preparation up to harvesting time.

The fertilizers, manures and water application levels were determined from the amounts applied per furrow and the number of crop points in it. Spacings of the crops were determined from the length of each furrow and the number of crop points in it. For the responses, for the first two weeks, each harvest (1st response) from each furrow was measured and averaged for the crop points in that furrow. The number of infected leaves, 2nd response, and the number of unharvested pods, 3rd response, were determined immediately after the 2-week harvesting. All the measurements were averaged for several furrows for each farmer.

2.2 Area

Kandara division/ constituency is located in Murang'a county as an administrative division. It's located at an elevation of 1755 metres above sea level. The location's co-ordinates on the globe are 0°49'60" S and 36°58'60" E. The soil type is generally loam and is suitable for crops cultivation [18].

2.3 Assumptions

1. Farmers provided accurate and reliable information during sample survey exercise.
2. All the data were normally distributed with insignificant errors in measurements.
3. Infected leaves were enough in determining the crops' health.
4. All the pods considered were suitable for export and consumption purposes.

3 Data Analysis, Results and Discussion

Descriptive analysis was done using contingency tables, charts (pie, bar) and graphs like normal curves and histograms. The inferential statistics were achieved using t-tests, Wilcoxon tests, ANOVA, proportion tests and regressions.

3.1 Descriptive statistics

Most of the analysis made use of histograms because most of the data were quantitative or numerical in nature.

Table 1. Summary of the variables with two categories only

Variable	Categories	Frequency (n)	Percent (%)
Gender	Male	24	56.0
	Female	19	44.0
Manure Source	Cows	41	95.3
	Goats/Sheep	2	4.7
Watered Times	Three	34	79.1
	Four	9	20.9
Infected Leaves	No	3	7.0
	Yes	40	93.0

From Table 1, most of the farmers sampled were males (56%), while female farmers were 44%. Cows provide manure to almost all the farmers in the region (95.3%). Most of the farmers irrigate their crops thrice in a week (79.1%) while only 20.9% of the sampled farmers water crops four times per week. 93% of the crops in farmers' fields are infected with diseases/pests.

Table 2. Summary on numerical variables

Variable	Min	Q₁	Median	Mean	Q₃	Max	Std. Dev.
Manure	18	21.75	24.7	24.69	27.6	30.8	3.621
Spacing	6.8	8.55	9.2	9.809	11.4	13.6	1.993
Yield	7.3	9.2	9.9	9.96	10.85	13.4	1.224
Pods	8	10	12	11.58	13	15	1.829
D.A.P	3.0	4.1	4.7	4.747	5.2	8.3	0.984
C.A.N	2.1	2.3	2.5	2.491	2.7	3.2	0.249
Water	3.1	3.75	4.4	4.381	5.05	5.7	0.829
Age	19	24	29	29.37	34.5	44	6.880

Table 2, The mean and median values of all the variables are close to each other.

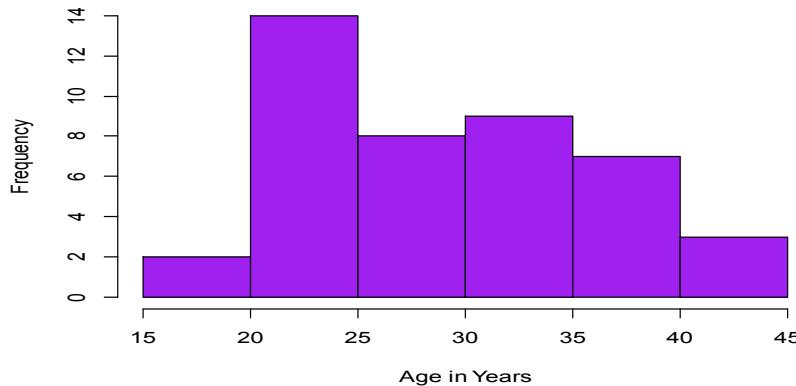
Histogram on Age of Participants**Fig. 1. Age of the participants**

Fig. 1 shows that; the majority of the participants were aged between 20 and 25 years. However, most of them fall between 20 and 40 years of age with only few being aged below 20 and above 40 years. It can also be noted that age data is not normally distributed.

Fig. 2 shows that the majority of French bean farmers in the area have 8 members in total- about 18%. This is closely followed by the families with 2 and 4 members- about 16% for each. No family was found to have a single member.

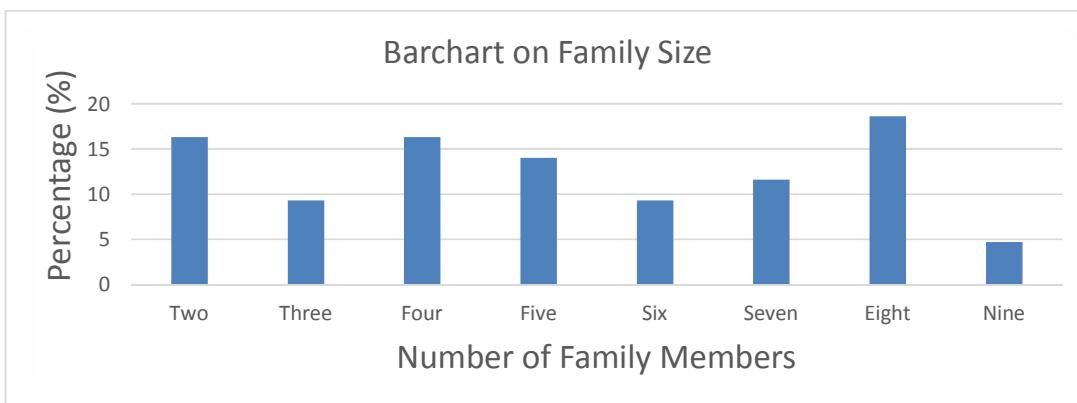


Fig. 2. Families' sizes of the French bean farmers

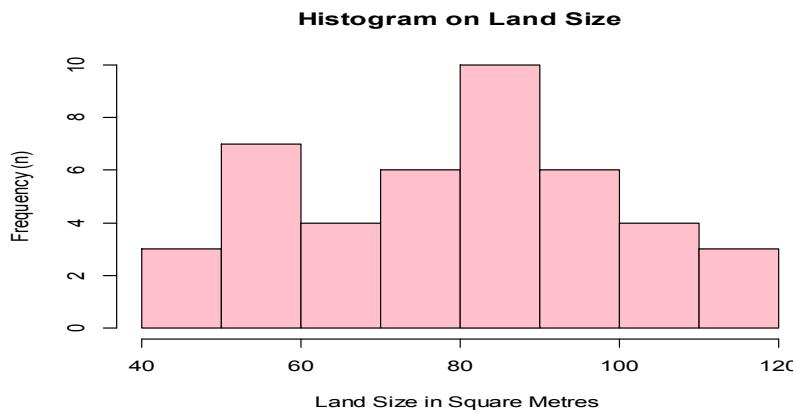


Fig. 3. Land sizes under French beans cultivation

The land size under French beans farming can be viewed as almost normally distributed, Fig. 3. The bin with most farmers has a land size between 80 and 90 m². The bins with the fewest farmers represent lands of sizes less than 50 m² and more than 110 m².

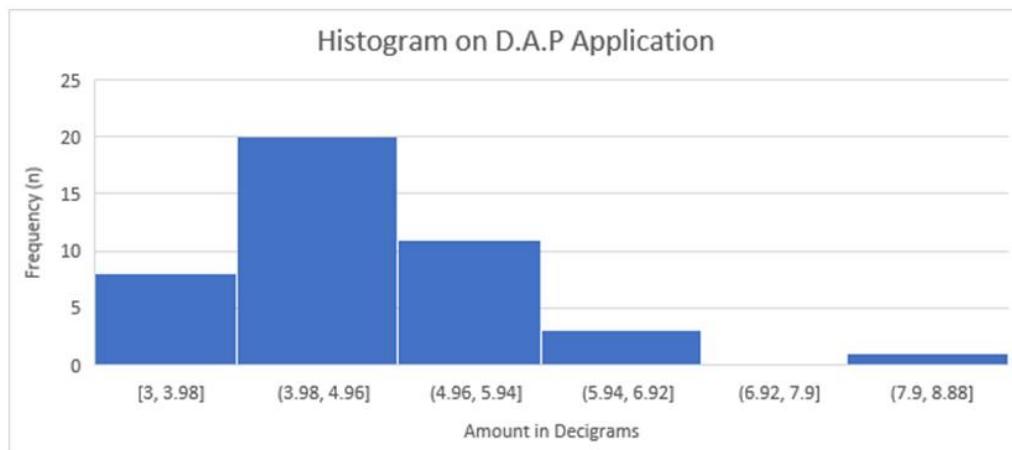


Fig. 4. Amount of D.A.P fertilizer application

From Fig. 4, it is seen that most of the farmers apply D.A.P fertilizer at 4 to 5 dg per crop point. Those applying between 8 and 9 dg are almost negligible. The application of D.A.P is not normally distributed as it has been evidenced by the shape formed by the bins in the same figure.

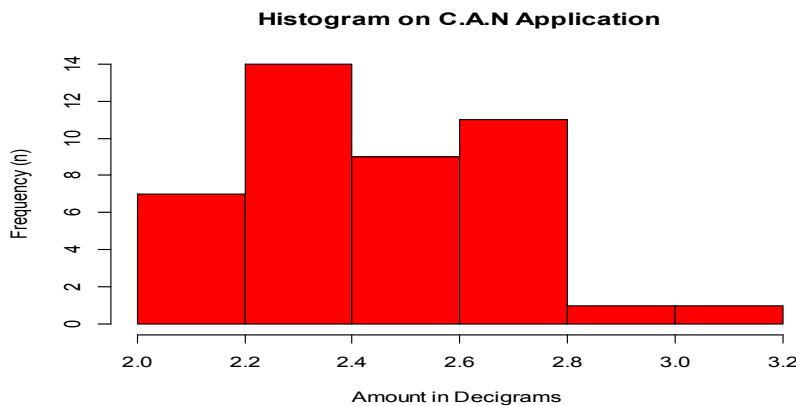


Fig. 5. Quantity of the C.A.N fertilizers application

The data represented by Fig. 5 shows that most of the farmers apply C.A.N fertilizer at 2.2 to 2.4 dg per crop point. Very few farmers use above 2.8 per crop point. The histogram doesn't show the shape of normal distribution.

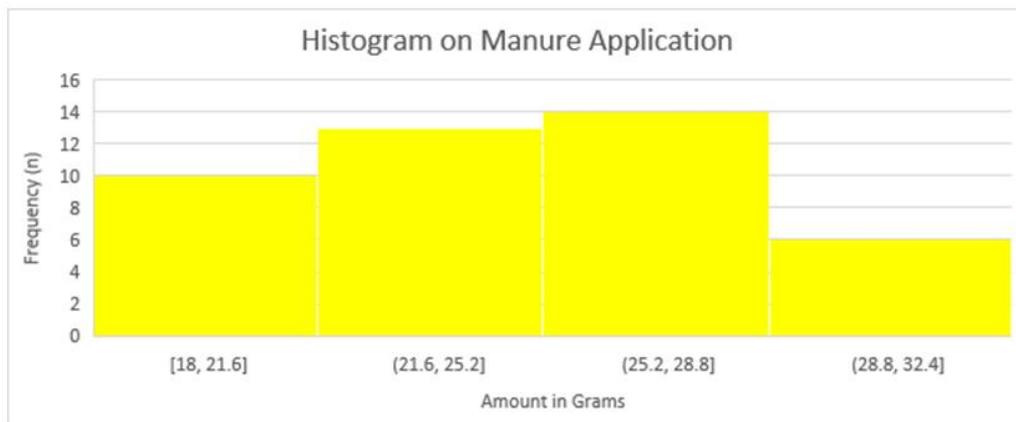


Fig. 6. Organic manures application for French beans

The application of manure is not normally distributed as can be seen from the shape of Fig. 6. Majority of the farmers use between 26 and 28 g on each crop point. Very few farmers apply above 28 g.

The histogram in Fig. 7 shows that the majority of the farmers have each crop point receiving between 3 and 3.5 ℥ in a week. Only a small percentage of the farmers irrigate each crop point with above 5.5 ℥ per week. The data is not normally distributed.

The histogram in Fig. 8 shows the shape of a non-normally distributed data on spacing. Majority of the farmers have their crops spaced between 9 and 10. Very few farmers have their spacing above 13 and below 7 cm.

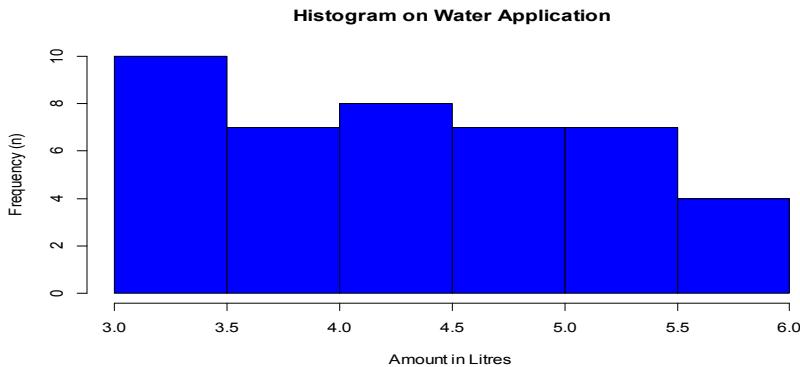


Fig. 7. Quantity of irrigating water applied by farmers

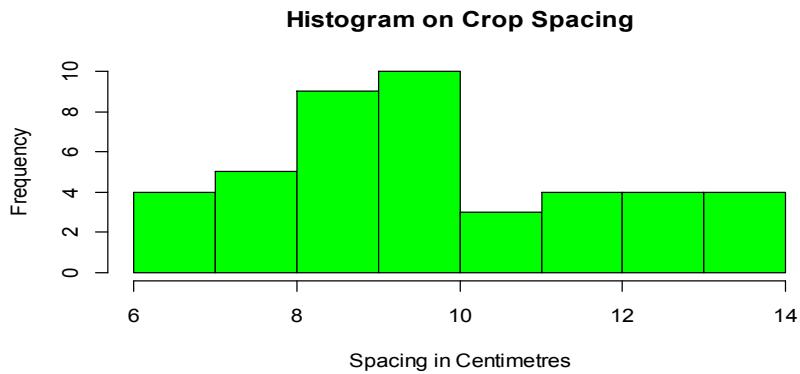


Fig. 8. French beans crops' spacing

Table 3. Level of crop infection

No. of leaves	0	1	2	3	4	5	6	7	8
Frequency	3 (7%)	7 (16%)	1 (2%)	3 (7%)	3 (7%)	3 (7%)	10 (23%)	5 (12%)	8 (19%)

Most of the crops in the field have 6 leaves that have infections on average, Table 3. This is represented by 23% and is followed by those with 8 infected leaves which is 19%. Those without any blemish are 7%, which is the case with those having 3, 4 and 5 blemished leaves.

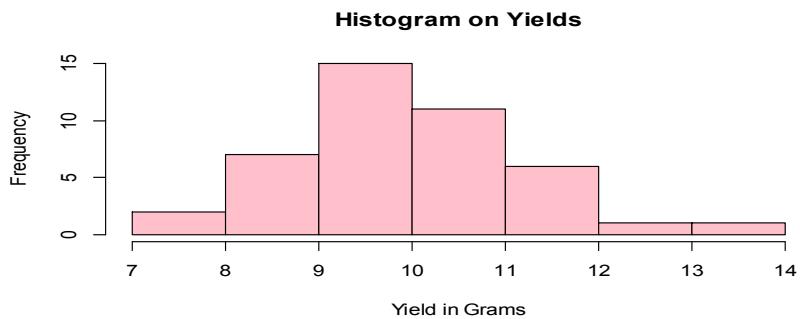


Fig. 9. Mass of French beans harvested by farmers on average

The histogram, Fig. 9, assumes the shape of Gaussian distribution. It suggests that our yield data can be assumed to be normally distributed. The figure also shows that the mode lies between 9 and 10 g. The same

histogram also indicates that those farmers who harvest less than 8 g and more than 12 g are very few, while no one obtains less than 7 or more than 14 g per crop point.

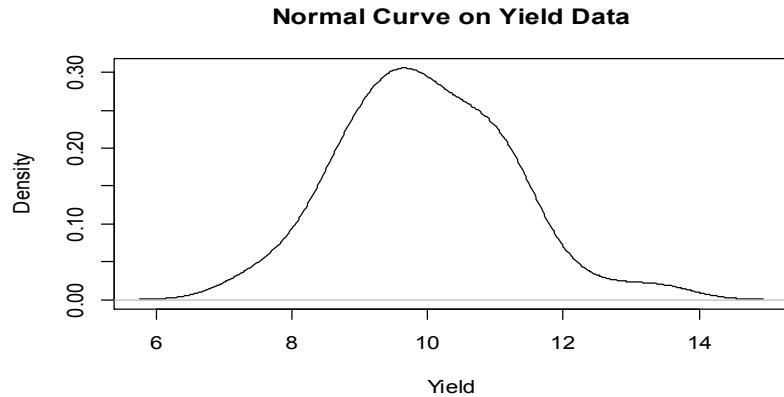


Fig. 10. Plot of normal curve on mass of harvested snaps

The curve in Fig. 10 on yield data assumes that of Gaussian distribution. It supports our observations from Fig. 9.

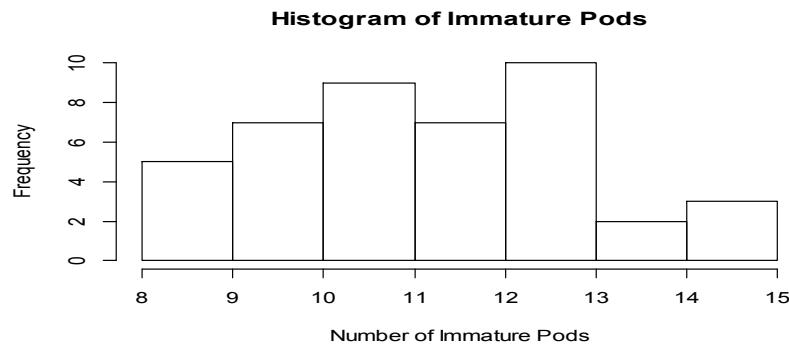


Fig. 11. The number of immature pods after 2-week harvest

From Fig. 11, it can be seen that the data on unharvested pods is almost normally distributed.

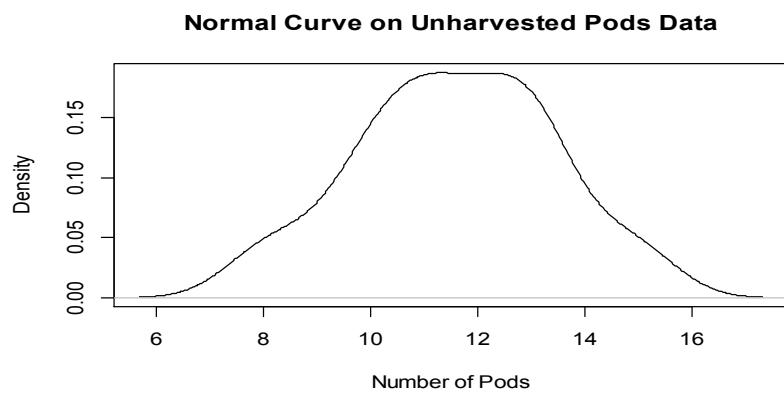


Fig. 12. Immature Pods' normal curve

Fig. 12 takes on the form of data that is normally distributed. Therefore, unharvested pods are normally distributed.

NB: It was realized that all the farmers had a uniform way of determining the row spacing. This was the length of the foot of an adult which was averaging at 27 cm. Therefore, the question on spacing of rows was removed from the questionnaire after the pilot survey since the results were uniform for all the farmers.

3.2 Inferential statistics

In this part of statistics, most of the testing was based on regressions to help determine if there is any relationship among qualitative data variables. All the tests in this research are carried out at $\alpha = 5\%$ level of significance.

(a) Tests on Proportions

H_0 : Two proportions of a given variable are equal. versus

H_1 : Two proportions of a given variable are not equal.

Table 4. Equality of proportions

Variable	Chi-square	df	P-value	95% C. I
Gender	0.37209	1	.54	[0.2940528, 0.5999197]
Manure Source	33.581	1	.00	[0.8294402, 0.9919028]
Times Watered	13.395	1	.00	[0.6351902, 0.8942428]
Presence of Infection	30.14	1	.00	[0.018193, 0.201226]

From Table 4 of output, it can be concluded that the null hypothesis for gender proportions is not rejected while the null hypotheses corresponding to the rest of variables are rejected. Considering the proportions for male and female farmers, the $P = .54$ is greater than $\alpha = .05$ level of significance and hence the null hypothesis is retained. The conclusion is that the female and male farmers' proportions are equal in the region statistically. The p-values corresponding to sources of manures, the number of times the crops are irrigated and the presence of infections on crops are all less than the 5% level of significance, and their null hypotheses are rejected. Therefore, cows provide manures to most of the farmers, those irrigating crops thrice are more than those irrigating four times in a week while most of crops are unhealthy in the fields.

(b) Tests on Relationships (Regressions)

In this section, tests are performed to investigate whether a given variable can be used to predict another variable. The hypotheses tested in these cases take/are of the general form:

H_0 : The linear relationship between variables in a specified pair is not significant. versus

H_1 : The linear relationship between variables in a specified pair is significant.

Table 5 has all the P -values, highlighted in green colour, greater than $\alpha = .05$ level of significance. This indicates that the null hypothesis should be retained and the conclusion made that there is no significant relationship between any two specified variables. All the multiple and adjusted R^2 values are extremely small hence no variable in a selected pair can be used to explain variation in the other variable. All the models' P -values are greater than the 5% level of significance and this signifies that the linear regressions performed are not adequate. From the scatter plots that were developed, no plot showed any form of relationship- be it linear or nonlinear- between any two variables in a given pair.

For the case of regression between the number of unharvested pods and selected variables, Poisson log-linear model was fitted since the pods are just counts that are assumed to follow the Poisson distribution.

H_0 : There is no significant relationship between a given variable and the number of unharvested pods obtained. versus

H_1 : There is a significant relationship between a given variable and the number of unharvested pods obtained.

Table 5. Regression analysis of selected variables

Variables	Predictors	Estimates	p-values	Multiple R ²	F-values	Model's P-values
Land size vs Family	Intercept Family	81.110 -0.251	.00 .86	0.001	0.034	.86
Land size vs Age	Intercept Age	59.280 0.699	.00 .11	0.060	2.602	.86
Yield vs Land size	Intercept Land	10.380 -0.005	.00 .59	0.007	0.296	.59
Yield vs D.A.P	Intercept D.A.P	9.170 0.167	.00 .39	0.018	0.748	.39
Yield vs C.A.N	Intercept C.A.N	8.019 0.780	.00 .31	0.025	1.055	.31
Yield vs Manure	Intercept Manures	8.058 0.077	.00 .14	0.052	2.247	.14
Yield vs Water	Intercept Water	10.540 -0.132	.00 .57	0.008	0.332	.57
Yield vs Spacing	Intercept Spacing	9.604 0.036	.00 .71	0.004	0.144	.71

Table 6. Poisson log-linear model on number of pods

Variable	Estimate	Std. Error	z value	p-value
Intercept	2.682	0.818	3.279	.00
Age	-0.005	0.007	-0.749	.45
Family Size	0.014	0.022	0.645	.52
Land Size	0.0002	0.003	0.097	.92
D.A.P Fertilizer	-0.028	0.050	-0.560	.58
C.A.N Fertilizer	0.072	0.186	0.387	.70
Manure Amount	-0.005	0.013	-0.364	.72
Water Amount	-0.039	0.057	-0.686	.49
Spacing	0.007	0.026	0.290	.77

$$\log(\mu) = 2.682 - 0.0054 * \text{Age} + 0.014 * \text{FamilySize} + 0.0002 * \text{LandSize} - 0.028 * \text{D.A.P} + 0.072 * \text{C.A.N} - 0.005 * \text{ManureAmount} - 0.039 * \text{WaterAmount} + 0.007 * \text{Spacing}$$

From the output in Table 6, it can be seen that all the p-values, highlighted in green colour, are greater than the 5% level of significance and hence the null hypothesis is retained. Therefore, the independent variables in the model (age, family size, land size, D.A.P, C.A.N, manure, water and spacing applied) are not significant in predicting the number of immature pods from the crops. This means that the relationship between the number of pods and the selected variables is not significant.

(c) T-tests on Means of Responses and Factors

In this section of t-tests, yield and spacing variables have been analysed since the data for the two variables are approximately normally distributed (seen before from histograms). In these cases, the hypotheses to be tested take the general form:

H_0 : The mean of a given response is equal across the two categories of a selected variable. verse

H_1 : The mean of a given response is different across the two categories of a selected variable.

Table 7. T-tests on mean responses across categories of selected variables

Responses	Categorical variables	t-values	p-values	95% C. I
Yield	Gender	0.819	.42	[-0.434, 1.030]
	Watered Times	3.723	.00	[-2.036, -0.562]
Unharvested Pods	Gender	0.326	.75	[-0.957, 1.325]
	Watered Times	0.758	.46	[-0.987, 2.045]

From Table 7, all the p-values are greater than .05 level of significance except for the case of the number of times of watering the beans in yield response ($P = 0.00 < \alpha = .05$). This means that all the null hypotheses are retained and conclusion made that all the mean responses are equal across the categories of the selected variables except for watered times in which the null hypothesis is rejected and conclusion made that the mean yield for the farmers who irrigate their crops thrice in a week (10.23) is higher than that of farmers who irrigate four times in a week (8.93). Therefore, the two categories of the selected variables produce the same output of French beans (whether in form of yield or unharvested pods) except for the number of times the crops are watered for the response yield. Further, all the 95% confidence intervals contain 0 except for the watered times for yield response.

(d) The Wilcoxon-Rank-Sum Tests

This section of tests deals with variables that are not approximately normally distributed (seen before from histograms). The variables include the age of farmers, D.A.P, C.A.N, Manure, Spacing, Land size and Water applications. The Wilcoxon-Rank-Sum tests have been used since the samples are not paired but independent.

H_0 : A given variable is the same across gender. versus

H_1 : A given variable is different across gender.

Table 8. Wilcoxon on variables across gender

Variables Vs Gender	w-value	p-value
Age	189	.35
Land Size	221	.88
D.A.P Application	204	.56
C.A.N Application	281	.19
Manure Application	238	.82
Crop Spacing	242	.74
Watered Amount	208.5	.64

Table 8 of output from Wilcoxon-Rank-Sum tests has all the P -values are greater than .05 level of significance. This indicates that all the null hypotheses are retained. The conclusion is that age of farmers is the same across gender, land size under French beans cultivation is the same across gender, D.A.P, C.A.N, Manure and Water amount for irrigation applied as well as crop spacing are the same for both male and female farmers.

Performing the Kruskal-Wallis tests on the non-normal variables Land size, D.A.P, C.A.N, Manure, Spacing and Water across the categories of family size and infected leaves yields the same results that all are the same across the categories.

(e) The Analysis of Variances (ANOVA)

In this section, the Analysis of Variances (ANOVA) was performed on approximately normally distributed variables. These are Yield and Crop Spacing variables. In these cases, the hypotheses to be tested take the general form:

H_0 : The mean of specified response is the same across all the categories of the selected variable. versus
 H_1 : The mean of specified response is different across all the categories of the selected variable.

Table 9. The ANOVA tables in summary

Response	Categorical variables	df	Sum of squares	F-value	P-value
Yield	Family Size	(1,41)	0.30	0.193	.66
	Infected Leaves	(1,41)	5.53	3.957	.05
Unharvested Pods	Family Size	(1,41)	5.52	1.677	.20
	Infected Leaves	(1,41)	7.87	2.432	.13

From Table 9, all the *P*-values are greater than .05 level of significance. Therefore, the null hypothesis is retained. The conclusion is that the means of yield and number of unharvested pods are the same across all the categories of the selected variables.

3.3 Discussion

Table 10 is a summary of what it means by inputs and outputs based on literature and what farmers are operating at. The figures in brackets are measurements per crop point on average. As can be seen, recommended and farmers' spacing yield a different number of crops in an acre of land. Translating these into inputs, farmers apply fewer manures, D.A.P and C.A.N while applying more water per crop point than what is recommended. This can be due to the fact that water is not bought or offered by companies but always available in plenty from rivers, ponds and streams and hence farmers can apply as much as they want. Although farmers receive enough inputs on inorganic fertilizers from French bean companies, they do not apply the same as advised by the companies' staff. This is in agreement with other researchers that the farmers from developing countries ration the inputs because they do not take French beans as high-input-demanding crops and this affects outputs negatively. For the case of outputs, farmers produce output that is very far from the upper limit of the recommended tonnes (t) per acre and the crops are unhealthy as evidenced by the number of infected leaves. Therefore, there is rationing of inputs, excess watering of crops, low production of French beans and evidence of unhealthy crops in Kariua region.

Table 10. Comparison of sample survey results with recommended results

	Land Size (m²)	Spacing (cm)	Crop Points
Recommended	4047 (Acre)	15 by 30	89933
Survey	4047 (Acre)	9.8 by 27	152948
Input			
	Manure (t)	D.A.P (kg)	C.A.N (kg)
Recommended	7.0 (77.8g)	80.0 (8.9g)	60.0 (6.7g)
Survey	3.8 (24.7g)	71.9 (4.7dg)	38.2 (2.5dg)
Response			
	Yield (t)	Pods (*10³)	Infection (*10³)
Recommended	4 -18		
Survey	6.1	1835 (12)	765 (5)

During the data collection exercise, a large number of intercrops was evident in the region as well as very small pieces of land, as shown in the photographs taken during the exercise. This is supported by the statistics above on spacing of the crops in which on average the spacing is 9.809 centimetres. This spacing is very far from the recommended spacing of 15 cm at minimum. Although this can be termed as poor farming techniques due to poor spacing and intercropping, the reality at the ground level cannot accept anything contrary. Therefore, the results from the sample survey indicate that there is poor spacing of crops, presence of diseases/infections, intercropping, too much water for crops, limited resources and low yields. The pods were subjected to strict selection of unwanted ones from the suitable ones to ensure that only the acceptable

was considered for mass recording. This revealed that most of the output from the farmers was rejected due to unsuitability for export.

It can be noted that the recommended input levels of the factors depend on some factors such as fertility of the soils, varieties of the French beans involved, climatic conditions, way of tilling and weeding and so on. This means that soil analysis is required before application of the fertilizers and manures (farmyard manure).

4 Conclusions and Recommendations

4.1 Conclusions

From the analysis, it is clear that in all tests, the mean yield is different across the number-of-times the farmers irrigate their crops per week. Those who irrigate their beans four times in a week experience/harvest lower mean yield compared to those who irrigate three times. That means, the increase in water for irrigation lowers yield. Also, the proportion of crops infected is greater than that of uninfected crops, based on presence or absence of abnormal leaves, hence more crops are infected in the area. Statistically, cows provide manure to most of the farmers at Kariua area and most of the farmers in the region irrigate their crops thrice in a week. The mean yield of 9.96 grams per crop point in a given harvest is evidence of low production of this crop. It is evident that no input can be used to predict yield in Kariua area. Even spacing, that is meant to help crops increase in yield, has no relationship with yields and infections. This is a sign of an underlying problem(s) that needs to be investigated in order to advise farmers accordingly.

The data and the photographs taken during the sample survey are available for reference.

4.2 Recommendations

Research to be done to determine the loss incurred by farmers due to unwanted pods (mainly due to unwanted shapes and sizes as well as infections). This is because there were a lot of pods that went into waste when determining the suitable pods to be considered for mass recording during the sample survey exercise.

Competing Interests

Authors have declared that no competing interests exist.

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