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The effect of phosphorus and potassium fertilizers on the growth and yield of yellow grams (*Vigna radiata L.*)

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Abstract
Yellow gram is a cheap source of protein often grown by small scale farmers in Kenya; it is well adapted to even in areas that receive less optimal rainfall and matures in less than 120 days. Yellow gram crop is widely grown and a cheap source of protein for inhabitants in Kisii region; its productivity continues to decline despite the continued use of nitrogenous and phosphate fertilizers. Previous research done has shown that yellow grams do not respond well to nitrogen and phosphorus unless the soils are deficient in these nutrients. Consequently, the growth and yield of Yellow gram depends on fertilizer requirements among other factors such as climate and agronomic practices. This research was done to determine optimal levels of potassium and phosphorus inorganic fertilizers application to realize maximum yields of yellow gram production in the region. A Randomized complete block design (RCBD) experiment consisting of three replicates was carried out in Magwagwa area of Kisii County between September to December, 2018. This experiment was carried out on red volcanic soils having 0.12% N, 15 ppm P_20_5 and 56 ppm K_2O. The treatments were: three levels of potassium fertilizer (K0: No potassium (control); K1:20 kg K/ha; and K2:30 kg K/ha) and the second factor was three levels of phosphorus (P0: No phosphorus (control); P1: 20 kg P/ha; and P2: 30 kg P/ha). The effect(s) of the treatment combinations on stem height (in cm), branch number per plant, pod number per plant, pod length (in cm), number of seeds per pod, 100-seed weight, and grain yield per hectare were evaluated. The data collected was subjected to Analysis of Variance (ANOVA) using SPSS 21.0 tool to determine the effect of different treatments. Significant differences in results of the treatments were separated using the Least Square Differences (LSD). Results revealed that different levels of K and P fertilizer application significantly ($p<0.05$) influenced the growth and yield of Yellow grams. The maximum plant height (94.8 cm), branch number (12/plant), number of pods (98/plant), seed number (10 seeds/pod), length of pod (10 cm), 100-seed weight (29.78 g) and grain yield (4414 kg/ha) were recorded from plots that received 30 kg/ha K_2O and 30 kg/ha P_2O_5, while the control recorded the lowest results. The 30 kg P_2O_5/ha and 30 kg K_2O/ha fertilizer levels enhance yields immensely and were directly proportional to branch density, pod formation and pod length.

Keywords: phosphorous, potassium, yellow grams, yields

1. Introduction

Food security remains a challenge to small holder, low income farmers in Kenya which has been aggravated by climate change. Diversification of crop production is one of the approaches to mitigate against changing climate. Grams (mung bean) are grown for their seed (as food), or for hay, green manure or as a cover crop. Yellow grams are one of the legume crops that contribute to cheap source of protein to low income families. Pulse protein is rich in amino acids like isoleucine, leucine, lysine, and valine. Grams are excellent sources of plant protein, fibre, minerals, vitamins, and polyphenols such as *Vitexine* and *Isovitexine* thus making the crop superior for human consumption. The demand for grams far outstrips its production in Kenya. Kenya currently produces about 121,076 metric tons against a demand of 127,130 metric tons (MOA, 2015) [15]. The major producing regions are located in the eastern, Coast, Nyanza, and parts of the Rift Valley. The average yields per hectare is 0.45 Metric tons (MOA, 2015) [15] as opposed to a research potential of 1.2 tons per hectare. Kimiti *et al*. (2009) found that the range of the green gram yield was 30–416 kg ha−1. But the on-station research recommendations indicate that the range of the potential yields is 300–1500 kg ha−1 (Karanja *et al*., 2006) [11].

The low mung bean productivity in Kenya has been attributed to many factors including low soil fertility, use of non-certified seed, non-application of fertilizers; poor agronomic practices (Kisii County Annual Report, 2015: KALRO, 2009) [9]; what can be generalized as poor agricultural practices. To achieve high mungbean yields, it requires improved management of growth environment of the crop. Growth, yield and quality of plant species differ with soil types, soil nutrient status, and fertilizer management; and a plant species requires suitable soil for higher yield and better quality (Hossain, *et al*. 2011) [1]. Mungbeans improves soil fertility by fixing atmospheric nitrogen through the process of symbiosis with proper rhizobium strain. Potassium is important in regulating the uptake of phosphorous. Enzymes that facilitate the formation of sugar, starch plus protein are affected by potassium in crops (Bukhsh, et a., 2011) [4].

The production of yellow grams in Kisii region, Kenya, has been adversely affected due to nutrient deficient soils especially that of phosphorus and potassium. Declining growth and yields of yellow grams has posed a challenge to small holder farmers in the region. Yellow grams do not respond well to phosphorus fertilizer application unless soils are very deficient which will necessitate its use (KALRO, 2006) [10]. This study therefore sought to establish the suitable levels of phosphorus and potassium fertilizers that can be applied to produce optimum growth and yield of yellow grams.

2. Materials and Methods

2.1 Site Description

The study was undertaken at Magwagwa location, Kisii Region in Western Kenya. The area lies within the upper midland Agro-ecological zone with modified tropical climate and at an altitude of 1722 m above sea level. The area receives bimodal rains with an average rainfall of up to 1600mm/year. The long rains occur between March and June, and the short rains occur between September and November. The area is humid with average temperature range of 21º C – 30º C maximum and 15ºC-20ºC minimum. The soils are red volcanic, deep and rich in organic matter; but have low soil fertility due to low mineral content and low cation exchange capacity (Jaetzold *et al*., 2006) [8].

2.2 Field Experiment

A Randomized Complete Block Design (RCBD) experiment, with three replicates was carried out during the short rains September-December, 2018. A total of 27 experimental plots each measuring 2 m x 2 m, separated by 1m path between adjacent blocks was used. The treatment factors comprised of: three (3) levels of potassium (K), namely (i) the control, K0 = zero potassium; (ii) K1 = 20 kg K per ha; (iii) K2 = 30 kg K per ha; and 3 levels of co-variate factor phosphorus (P), namely (i) P0 = zero phosphorus (the control experiment); (ii) P1 = 20 kg P per ha and (iii) P2 = 30 kg P per ha. This gave rise to 9 treatment combinations as shown in table 2.1 that were randomly replicated in three blocks.

Table 1: Treatment Combinations

	Doses of phosphorus		
Doses of Potassium	**P0**	**P1**	**P2**
K0	Control (K0P0)	0kgK+20kgP (K0P1)	0kgK+30kgP (K0P2)
K1	20kgK+0kgP (K1P0)	20kgK+20kgP (K1P1)	20kgK+30kgP (K1P2)
K2	30kgK+0kgP (K2P0)	30kgK+20kgP (K2P1)	30kgK+30kgP (K2P2)

2.3 Data collection

Random sampling of five plants from each plot avoiding border rows were used in collecting data. The growth parameters (stem height and branch number) were measured three times starting at 3 weeks after seed sowing while yield parameters (pod number, length of pod, seed number, weight of 100 seeds and grain yield) were measured at maturity stage of the crop.

2.4 Data analysis

The data collected was checked for consistency and completeness and then analyzed using SPSS 21.0 computer software. Analysis of Variance (ANOVA) was done to identify mean differences between treatment combinations; and the differences among means were separated using the least significant difference (LSD) test at 95% confidence level.

3. Results and Discussion

Plant Height

Stem length measurements was observed to vary under different fertilizer treatments and at different measurement intervals. Results are as shown in figures 3.1, 3.2, and 3.3 below.

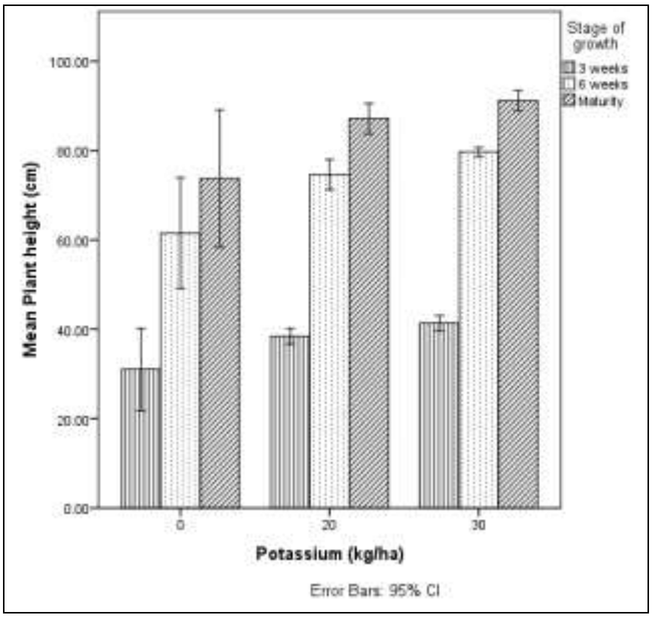

Fig 1: Effect of Potassium on Height of plant

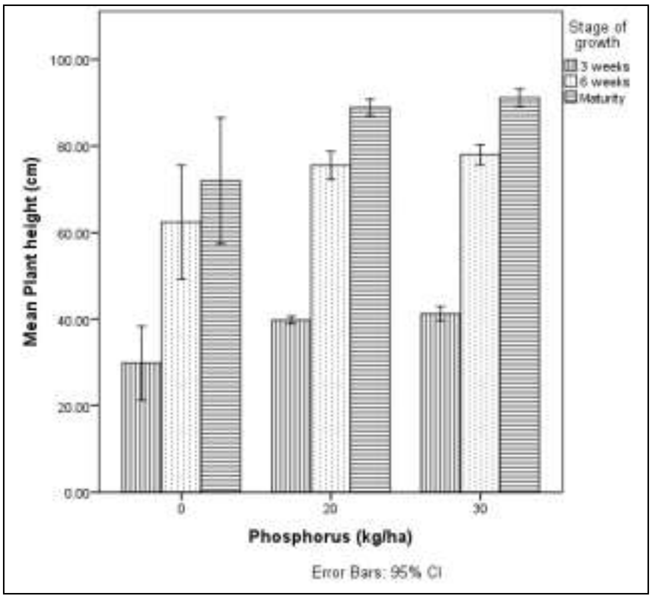

Fig 2: Effect of Phosphorus on Height of Stem

Figure 3.1 indicates that increase of potassium fertilizer application levels increases the plant height of yellow grams. Application of 30 kilograms of K_2O (potassium fertilizer) per hectare recorded 87.8 cm stem height, followed by 20 kg K_2O/ha with 81.18 cm while the control had the lowest plant height (70.6 cm).

Figure 3.2 shows that there were differences in the stem height of yellow grams under different phosphorus fertilizer application levels. Increasing phosphorus fertilizer application levels increased the stem heights whereby 30 kg P_2O_5/ha recorded the highest (89.4 cm), followed by 20 kg P_2O_5/ha (85.44 cm) and the control gave the shortest stem height (47 cm).

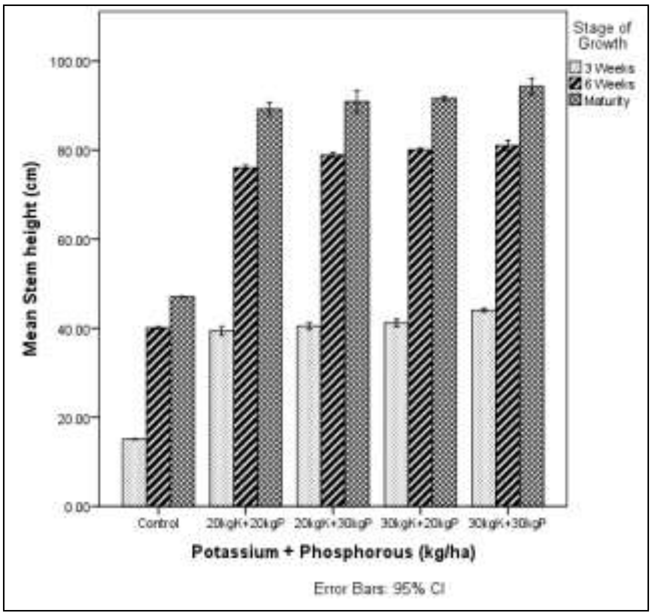

Fig 3: Effect of Combined Potassium & Phosphorus on Height of Stem

Figure 3.3 indicates that there were differences in the stem height of yellow grams under different combined potassium plus phosphorus fertilizer application levels. Combined fertilizer 30 kg K + 30 kg P per hectare recorded the highest stem height (94.8 cm).

Branch Number

The branch density was used as proxy measure to vigour of growth due to various levels of fertilizer applications. There were differences on the number of branches between treatments as seen in figures 3.4, 3.5, and 3.6 below.

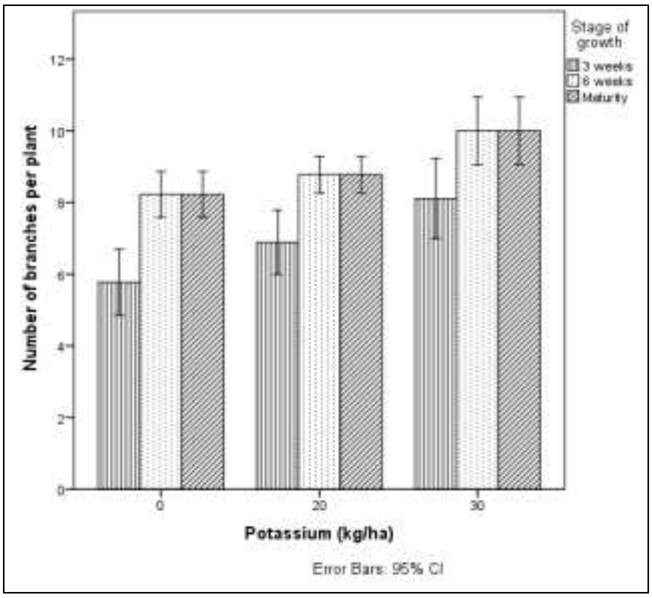

Fig 4: Effect of Potassium on Branch Number

There are observed differences in branch number between different levels of potassium used (figure 3.4). Potassium fertilizer applied in the amount 30 kg K_2O/ha recorded higher branches per plant (9), followed by 20 kg K_2O/ha (8) while the control recorded the least (7).

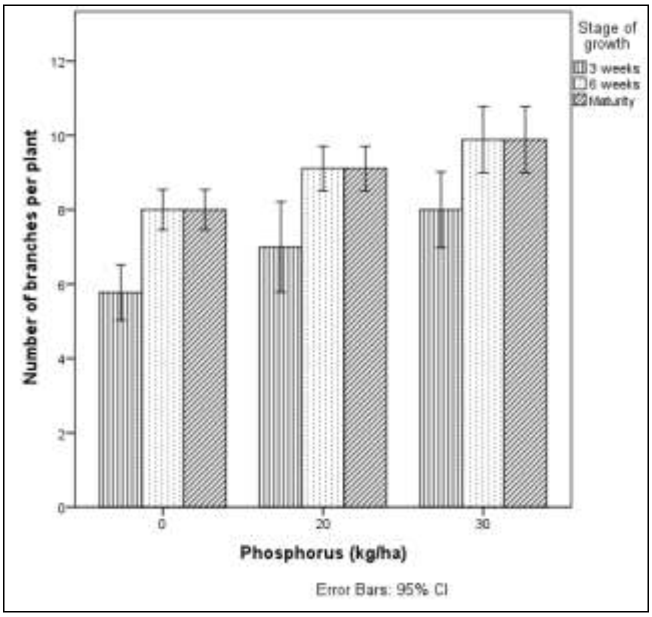

Fig 5: Effect of Phosphorus on Branch Number

Figure 3.5 shows that there were differences in branching density under different phosphorus treatments. The highest branch number per plant (9) was recorded when 30 kg P_2O_5/ha amount was used while the control recorded the least (7).

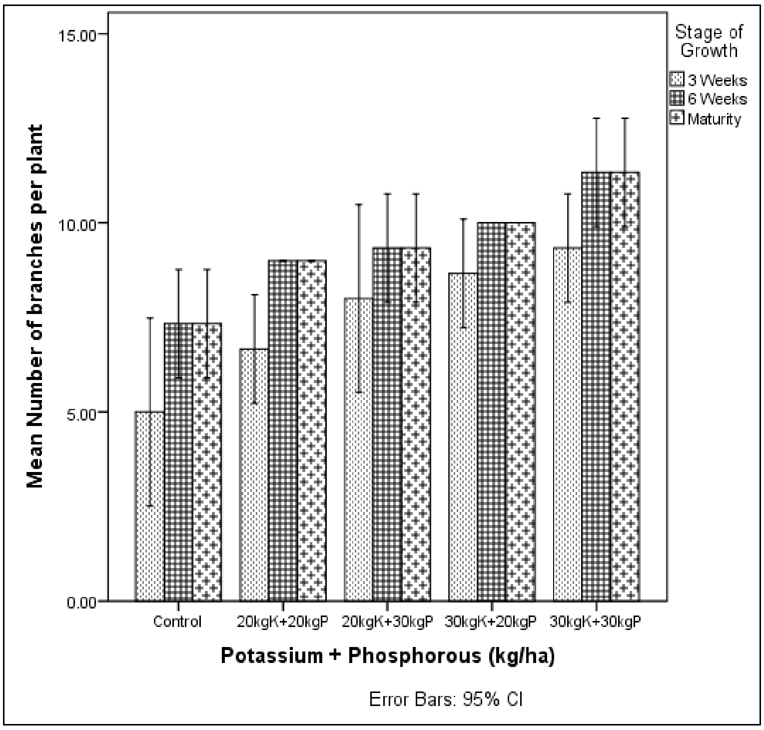

Fig 6: Effect of Potassium + Phosphorus on Branch Number

Figure 3.6 shows that the combined potassium and phosphorous doses do not seem to have influenced branching very much. However, the branch number increased to a maximum of 11 branches when combined fertilizer level of 30 kg K_2O/ha + 30 kg P_2O_5/ha were applied.

Table 2: Combined ANOVA Summary on Effect of Potassium and Phosphorus on Stem Height and Branch Numbers

Tests of Between-Subjects Effects						
Source	**Dependent Variable**	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
K	Plant height (cm)	3405.657	2	1702.828	3.744	.028
	Number of branches per plant	53.062	2	26.531	18.810	.000
P	Plant height (cm)	3771.509	2	1885.755	4.146	.020
	Number of branches per plant	54.395	2	27.198	19.282	.000
K * P	Plant height (cm)	2845.538	4	711.385	1.564	.193
	Number of branches per plant	4.272	4	1.068	.757	.557
Error	Plant height (cm)	32747.845	72	454.831		
	Number of branches per plant	101.556	72	1.410		
Total	Plant height (cm)	42770.549	80			
	Number of branches per plant	213.284	80			

The mean difference is significant at $p<0.05$ level.

Results indicated that Potassium and Phosphorus had significant effect on stem height and branching density ($p<0.05$). Analysis of variance (ANOVA) (table 3.1) revealed that application of potassium plus phosphorus combined did not give any significant difference in branch number and stem height. However, individual K and P fertilizers applied separately gave significant differences in stem height and branching density.

Table 3: Effect of Potassium on Plant Height and Number of Branches

Plant height (cm) Number of branches per plant * Potassium (kg/ha)		
Potassium (kg/ha)	**Plant height (cm)**	**Number of branches per plant**
0	55.4274 a	7.41 a
20	66.7311 ab	8.15 b
30	70.7422 b	9.37 c

Means having dissimilar letters are significantly different.

It was noted (table 3.2) that there were significant differences in stem height between the control and 30 kg K_2O/ha used, but 20 kg K_2O/ha and the control did not show any significant difference in stem height. Likewise, among fertilizer application rates of 30 kg K_2O/ha and 20 kg K_2O/ha never recorded any statistically significant difference in stem height. Thesiya, *et al*. (2013) reports that using potassium fertilizer significantly increase stem height in blackgram. Under branching density, it is confirmed that using potassium fertilizer significantly produce more branches at 30 kg K_2O/ha compared to both the control and 20 kg K_2O/ha (table 3.2). Similarly, 20 kg K_2O/ha significantly gave higher branches per plant than the control. Similar findings revealed that increase of potassium fertilizer significantly increase branching density in mungbean (Biswash, *et al*., 2014; Buriro, *et al*., 2015) [3, 5].

Table 4: Effect of Phosphorus on Plant Height and Branch Number

Plant height (cm) Number of branches per plant * Phosphorus (kg/ha)		
Phosphorus (kg/ha)	Plant height (cm)	Number of branches per plant
0	54.7230 a	7.26 a
20	68.0644 b	8.41 b
30	70.1133 b	9.26 c

Means having dissimilar letters are significantly different.

It was observed (table 3.3) that stem height of yellow gram crop was significantly taller when 30 kg P_2O_5/ha was applied as compared to that of the control. Likewise, the treatment with 20 kg P_2O_5/ha significantly produced taller plant stems than the control. However, between 20 kg P_2O_5/ha and 30 kg P_2O_5/ha fertilizer use did not show any significant difference in stem height. Therefore, using 30 kg P_2O_5/ha gives better stem length in yellow grams which might have resulted from the fact that phosphorus promotes plant vigour and makes the stem strong. Imran, *et al*. (2016) [7] found the same result where increasing phosphorus fertilizer application significantly increased plant height in mungbean. A post hoc test on the effect of phosphorus on branching density (table 3.3) revealed a significant difference between all three levels of phosphorus applied. This agrees with Akter, *et al*. (2019) [1] where branch numbers were highly influenced when phosphorus fertilizer was used in mungbean.

Pod Number

There were differences in number of pods under different Potassium and phosphorous fertilizer treatments. Different Potassium fertilizer application levels (30 kg K_2O/ha, 20 kg K_2O/ha and Nil (control)) recorded 91 pods, 82 pods and 74 pods respectively; figure 3.7 below.

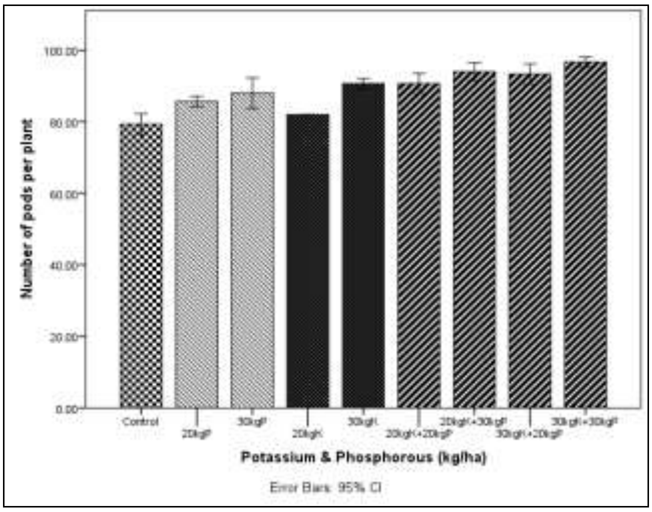

Fig 7: Treatment Effect on Pod Number

Pod Length

Pod lengths were measured and recorded for statistical analysis at maturity stage as shown in figure 3.8.

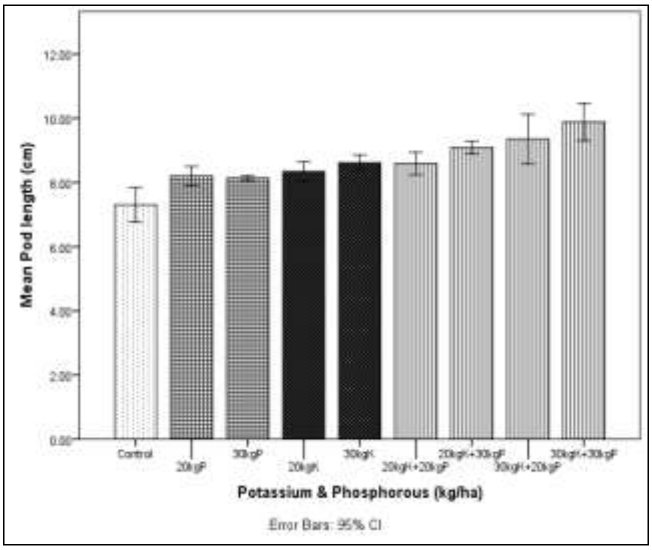

Fig 8: Treatment Effect in Pod Length

Figure 3.8 shows that there are differences in pod length under different Potassium and phosphorous levels of fertilizer application. The amount of Potassium + Phosphorus at 30 kg/ha recorded highest pod length (9.81 cm) while the control had the least pod length (7.46 cm).

Seed Number per Pod

It was observed that there were differences in the seed number in each pod for different treatments, figure 3.9.

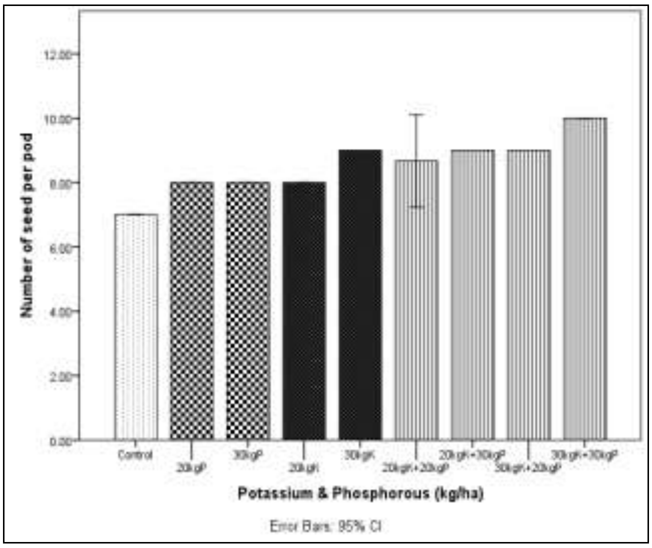

Fig 9: Effect of Treatment on Seed Number

Yield of Grain in Kilograms per Hectare

The Yellow gram crop was harvested at physiological maturity. The pods were shelled after sun drying for 2 days. Grains obtained from 1m^2 area from the center of each unit plot were dried to a moisture content of 13%. and weighed. This was used to calculate the grain yield in kg per hectare.

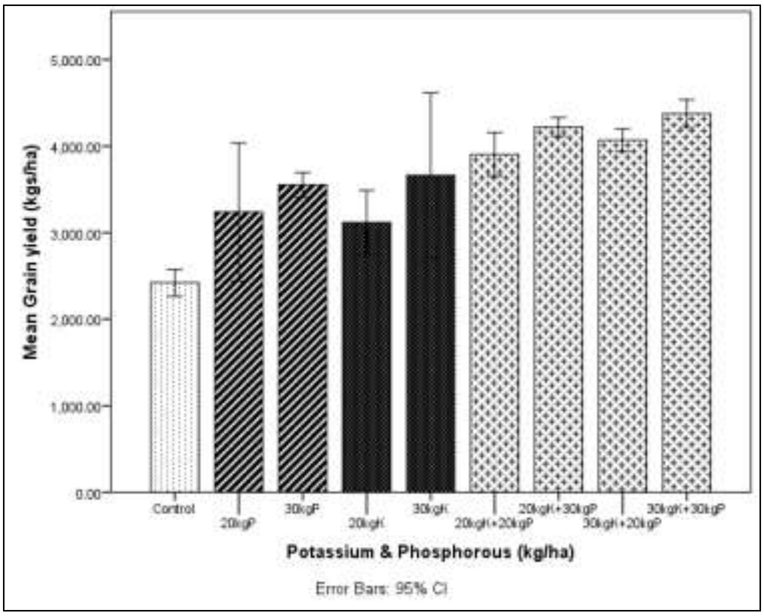

Fig 10: Treatment Effect on Grain Yield (kg) per Ha

There are observed differences in grain yield of Yellow grams between different treatments (figure 3.10). Potassium fertilizer applied in the amount of 30 kg K_2O/ha recorded the higher yield (3925 kg/ha) while the control had the lowest grain yield (2402 kg/ha). There were observed differences in the grain yield of yellow grams between the phosphorus fertilizer application levels. The control had the lowest grain yield (2402) while 30 kg P_2O_5/ha recorded higher yield (3599 kg/ha). Combination of potassium plus phosphorus fertilizer application yielded highest (4414 kg/ha) when 30 kg/ha of K + P fertilizer was used.

Table 5: Combined ANOVA Summary on Effect of Potassium and Phosphorus on Pod Number, Pod Length, 100-seed weight, Seed Number, and Grain Yield

Tests of Between-Subjects Effects						
Source	**Dependent Variable**	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
K	Number of pods per plant	606.889	2	303.444	282.517	.000
	Pod length (cm)	8.912	2	4.456	152.514	.000
	100-Seed weight (g)	201.230	2	100.615	66.356	.000
	Number of seeds per pod	12.519	2	6.259	169.000	.000
	Grain yield (kg/ha)	4410661.630	2	2205330.815	66.106	.000
P	Number of pods per plant	582.000	2	291.000	270.931	.000
	Pod length (cm)	4.193	2	2.096	71.749	.000
	100-Seed weight (g)	206.524	2	103.262	68.102	.000
	Number of seeds per pod	4.519	2	2.259	61.000	.000
	Grain yield (kg/ha)	4541768.296	2	2270884.148	68.071	.000
K * P	Number of pods per plant	88.444	4	22.111	20.586	.000
	Pod length (cm)	.610	4	.152	5.219	.006
	100-Seed weight (g)	9.830	4	2.457	1.621	.212
	Number of seeds per pod	1.037	4	.259	7.000	.001
	Grain yield (kg/ha)	215077.926	4	53769.481	1.612	.215
Error	Number of pods per plant	19.333	18	1.074		
	Pod length (cm)	.526	18	.029		
	100-Seed weight (g)	27.293	18	1.516		
	Number of seeds per pod	.667	18	.037		
	Grain yield (kg/ha)	600490.000	18	33360.556		
Total	Number of pods per plant	1296.667	26			
	Pod length (cm)	14.241	26			
	100-Seed weight (g)	444.877	26			
	Number of seeds per pod	18.741	26			
	Grain yield (kg/ha)	9767997.852	26			
The mean difference is significant at $p<0.05$ level.						

ANOVA results (table 3.4) revealed significant differences between potassium fertilizer application levels with p = 0.000 on the yield indicators. Similarly, phosphorous fertilizer showed significant results on all the yield indicators studied (table 3.4).

Combined K + P fertilizer use resulted in a significant effect in pod number, pod length, and seed number but there was no significance in 100-seed weight and grain yield.

Table 6: Effect of Potassium on Pod Number, Seed Number, Pod Length, 100-Seed Weight, and Grain Yield

Number of pods per plant Number of seeds per pod length (cm) 100-Seed weight (g) Grain yield (kg/ha) * Potassium (kg/ha)					
Potassium (kg/ha)	Number of pods per plant	Number of seeds per pod	Pod length (cm)	100-Seed weight (g)	Grain yield (kg/ha)
0	82.11 a	7.67 a	7.8811 a	20.7289 a	3070.67 a
20	88.89 b	8.56 b	8.6744 b	25.3044 b	3748.67 b
30	93.67 c	9.33 c	9.2844 c	27.2400 c	4034.44 c

Means having dissimilar letters are significantly different.

Post hoc test results (table 3.5) indicates that pod density per plant was statistically different between plots that received 30 kg K_2O/ha when compared with plots that received Nil(control) and 20 kg K_2O/ha. This agrees with Biswash, *et al*. (2014) [3] whose findings revealed that the use of Potassium fertilizer at increasing amount recorded statistical significance on pod number in blackgram. The seed number for each pod of the yellow grams substantially increased with the increase in the potassium fertilizer use. When 30 kg K_2O/ha was used highest seed number per pod (9) was recorded, followed by 20 kg K_2O/ha (8) and the control had the least seeds (7). Similarly, increase in potassium fertilizer significantly increased pod length and 100-seed weight.

It is evident that (table 3.5) there were statistical differences in yield of grain for different potassium treatments. Fertilizer use at an amount of 30 kg K_2O/ha gave a statistical difference in yield of grain as compared to 20 kg K_2O/ha and the control. Application of 20 kg K_2O/ha significantly produced higher grain yields than the control experiment. The high yield at 30 kg K_2O/ha fertilizer application could have been attributed to high pod density and seeds per pod. The findings are in line with Kumar, *et al*. (2014) [14]; Buriro, *et al*. (2015) [5] who found out that grain yield of mungbean improved significantly when potassium amount was increased.

Table 7: Effect of Phosphorus on Pod Number, Seed Number, Pod Length, 100-Seed Weight, and Grain Yield

Number of pods per plant Number of seeds Pod length (cm) 100-Seed weight (g) Grain yield (kg/ha) * Phosphorus (kg/ha)					
Phosphorus (kg/ha)	Number of pods per plant	Number of seeds per pod	Pod length (cm)	100-Seed weight (g)	Grain yield (kg/ha)
0	81.89 a	8.00 a	8.0878 a	20.7067 a	3066.67 a
20	89.89 b	8.56 b	8.7156 b	25.2311 b	3737.33 b
30	92.89 c	9.00 c	9.0367 c	27.3356 c	4049.78 c

Means having dissimilar letters are significantly different.

Post hoc test results (table 3.6) showed that the treatment with 30 kg P_2O_5/ha had significantly higher pod number over plots that received 20 kg P_2O_5/ha. It was also indicated that the use of phosphorus fertilizer of amount 20 kg P_2O_5/ha and 30 kg P_2O_5/ha recorded significantly higher pod number over the control. Increase in pod number per plant when phosphorus fertilizer is applied might be attributed to more branching density and longer stem height. Length of pod was statistically different between different amount of phosphorus fertilizer applied where the longest pod was recorded in 30 kg P_2O_5/ha use (table 3.6). Also, the use of 30 kg P_2O_5/ha produced significantly more seeds per pod than 20 kg P_2O_5/ha and control. The increase in seeds per pod could have been attributed to long pod formation. Similar results were reported that increased amount of phosphorus use significantly increased pod density and seeds per pod in mungbean (Murtaza, *et al*. 2014; Imran, *et al*. 2016) [16, 7]. It was evident that there were statistical differences in yield of grain for different phosphorus treatments. Fertilizer use at an amount of 30 kg P_2O_5/ha gave a statistical difference in yield of grain as compared to 20 kg P_2O_5/ha and the control. The high yield at 30 kg P_2O_5/ha fertilizer application could have been attributed to high pod density and seeds per pod. These findings are in line with Ali *et al*. (2010) [2] whose study on mungbean found out that there were significant differences in grain yield per ha when phosphorus fertilizer application was increased.

4. Conclusion

This study has revealed that growth and yield of yellow grams is depended upon potassium and phosphorous fertilizer use. Height of stem, branches per plant, pod number, seeds per pod, pod length, and grain yield of Yellow grams were significantly influenced when K and P fertilizers were applied. The optimum Potassium and phosphorus independent and combined fertilizer levels gave the highest yields at 30 kg/ha applications. However, stem height, branches per plant and 100-seed weight were non-significant when K and P in combination were applied. It can be concluded that phosphorus application of amount 30 kg P_2O_5/ha and potassium amount of 30 kg K_2O/ha could be applied to give higher yields of Yellow grams in Magwagwa location, Kisii Region-Kenya.

5. Recommendation

Based on the current study findings, it is recommended that phosphorus fertilizer at the amount of 30 kg P_2O_5/ha and potassium fertilizer at the amount of 30 kg K_2O/ha should be applied when growing yellow grams in an effort to promote high yields in Kisii region. It is also recommended that more work be done to establish the most efficient and profitable spacing and soil fertility management and other agronomic practices.

6. Acknowledgement

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7. References

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