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Growth, yield and quality response of snap bean (*Phaseolus vulgaris* L.*)* plants to different inorganic fertilizers applications in central Kenya.

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ABSTRACT

Objective: An on-farm trial was established under furrow irrigation in two seasons. The first season trial was planted on 5th March 2010 and the second season trial on 6th November 2010 at Kimbimbi in Kirinyaga South district, Kenya , to evaluate the effect of inorganic fertilizer application regimes on growth, yield and quality of snap beans.

Methodology and results: The fertilizer treatments comprised: (i) application of di-ammonium phosphate (DAP) at planting and topdressing with calcium ammonium nitrate (CAN) at 21 days after planting (dap); (ii) application of DAP at planting and topdressing with NPK-17:17:17 at 21 dap; (iii) application of DAP at planting, topdressing with CAN at 21 dap and topdressing with NPK-17:17:17 at 35 dap; (iv) application of CAN at planting, topdressing with CAN at 21 dap and then topdressing with CAN at 35 dap; (v) control (no fertilizer added). The varieties tested were Amy and Serengeti. The trial was laid out in a randomized complete block design with a factorial arrangement and replicated three times. The data collected included crop emergence, number of nodules per plant, nodule dry weight, shoot dry weight, root dry weight, pod yield and yield components. The results showed that inorganic fertilizer application depressed nodulation relative to the control. Generally, application of DAP-CAN and DAP-NPK significantly increased shoot dry weight while CAN alone had no effect. All treatments except DAP-NPK had significantly higher fine pod yield than the control in Amy while all fertilizer treatments improved fine pod yield in Serengeti. DAP-CAN fertilizer application had the most positive effect in Serengeti while DAP-CAN-NPK had the most positive effect in Amy. Snap bean growth and pod yield responses is dependent on genotype.

Conclusion and application: DAP-CAN fertilizer application on Serengeti plots had 40.7% and 344.1% higher net profit than the average profit of all the fertilizer treatments on Serengeti and Amy, respectively. Use of DAP-CAN fertilizer with variety Serengeti is the most profitable option for smallholder farmers in Mwea.

Key words: Extra fine pods, fine pods, Serengeti, Amy, inorganic fertilizer.

INTRODUCTION

Snap bean is an important export vegetable crop in Kenya, Tanzania, Uganda, Zambia, Zimbabwe and North Africa (Iruria *et al*., 2002). Snap bean in Kenya, accounts for 60% of all export vegetables and 21% of horticultural exports (HCDA, 2010), thus significantly contributing to national revenue. In 2009, Kenya exported 30,119 metric tonnes of snap beans valued at Kshs 4.33 billion (USD 55.9

million) mainly to the United Kingdom, Netherlands, France, Belgium and Germany (HCDA, 2010). Snap bean is grown as a cash crop by large and small holder farmers (CIAT, 2006). It creates on-farm employment opportunities for the rural communities especially women and youth. Lenne *et al*. (2005) estimated that more than 1 million people benefit from the snap bean sub-sector in Kenya. The major snap bean production areas in Kenya are Athi River, Kirinyaga, Meru and Naivasha (Monda *et al*., 2003). One of the major abiotic constraints to snap bean production in Kenya is low soil fertility. Nitrogen is the most deficient nutrient in the snap bean growing areas. In Mwea, soil analyses conducted before planting in both seasons have indicated that N is very low (0.09-0.12%), while P is present at adequate levels (44-57ppm). Production of snap bean is, however, highly intensive in terms of fertilizer use which accounts for about 20% of the total production costs for snap bean (MOA, 2004). Most farmers in Mwea use N and P containing fertilizers for snap bean production which is carried out under furrow irrigation, since rainfall in the area is unreliable. Snap bean is a heavy feeder and its production is best suited to friable, deep and well drained soils high in organic matter (KARI, 2007). The mineral nitrogen in the soil is mainly NO_{3-} and to a lesser extent ammonium (NH_{4+}). As nitrate is minimally adsorbed onto soil particles, it is very mobile resulting in leaching losses due to irrigation. The N nutrient from the inorganic fertilizers is leached leaving the soils depleted of N (Wangechi, 2009). Chemical fertilizers are often considered as solutions to current nutrient deficiencies in Mwea. However, farmers in the area use varying fertilizer application regimes for snap bean production whose effectiveness has not been established. Lack of good quality seed of locally adapted varieties is another major constraint to snap bean production in Kenya. Currently, there is dependence on few varieties whose seed availability has recently become unreliable. Therefore, a study was conducted to determine the effect of varying inorganic fertilizer application regimes on growth, yield and quality of two commercial snap bean varieties.

MATERIALS AND METHODS

Experimental site: The study was conducted in Kimbimbi area of Mwea east division, Kirinyaga South district in the Central province of Kenya. The site was in a farmer's field which is located 100 km Northeast of Nairobi on Longitude 37°21.9'E and latitude 0°36.1'S Mwea east division occupies the lower altitude zones of Kirinyaga South district, in an expansive lying, wet savannah ecosystem. The area receives an annual average precipitation of 826 mm per annum, with maximum rainfall occurring in April/May and October/November. The temperatures range from 16.5°C to 29°C. Since the rainfall is unreliable in the area, farmers normally irrigate their land and as a result some of the nutrients especially N are lost due to leaching. The soils at the site are classified as Nitisols (Kikuyu red loam) with good water holding capacity and aeration. They are characteristically red, dark red or dark reddish brown in colour. The soils at the site have an average pH of 5.2, with adequate levels of P average of 50.5 ppm but low in N average of 0.1 %. The first season planting was done on 5th March 2010 and mature pods were picked for five weeks until 27th June 2010. The second season planting was done on 6th November 2010 and plots were harvested for seven weeks until 12th February 2011. Furrow irrigation was used to provide water to the snap bean crop whenever there were no rains.

Experimental design treatments and crop husbandry: The experiment was laid out as a randomized complete block design with a factorial arrangement and replicated three times. Snap bean varieties used in this study were Amy and Serengeti. The treatments consisted of four inorganic fertilizer application regimes applied on varieties Amy and Serengeti: i. Control-no fertilizer; ii.CAN - 91 kg N/ha applied in three splits (23 kg N/ha applied as calcium ammonium nitrate (CAN) at planting, 23 kg N/ha as CAN at 21 days after planting (dap) and 45 kg N/ha as CAN at 35 dap); iii. DAP-CAN - 92 kg N/ha and 110 kg P_2O_5/ha (43

kg N/ha and 110 kg P_2O_5/ha both applied as diammonium phosphate (DAP) at planting and 49 kg N /ha applied as CAN at 21 dap, days after planting ; iv. DAP-CAN-NPK - 77 kg N/ha, 79 kg P_2O_5/ha and 21 kg K_2O/ha (23 kg N/ha, 58 kg P_2O_5/ha applied as DAP at planting, 33 kg N/ha as CAN at 21 dap, 21 kg N/ha, 21 kg P_2O_5/ha and 21 kg K_2O/ha as NPK (17:17:17) at 35 dap); v. DAP-NPK - 90 kg N/ha, 157 kg P_2O_5/ha and 47 kg K_2O/ha (43 kg N/ha and 110 kg P_2O_5/ha applied as DAP at planting and 47 kg N/ha and 47 kg P_2O_5/ha + 47 kg K_2O/ha as NPK(17:17:17) at 21 dap). There were three blocks comprising ten experimental plots containing combinations of the two varieties and the five fertilizer application regimes. Each experimental plot measured 3.5 m by 3.0 m, with 0.5m and 1m paths between the plots and blocks respectively. Snap bean varieties Amy and Serengeti were dressed with Monceren GTFS 390® (active ingredients Imidacloprid, Thiram and Pencycuron) at the rate of 8 ml/kg seed to control bean fly, and kept under shade to dry. The seed rate was 50 kg seed per hectare in single rows of 60 cm apart and 10 cm within rows. Two seeds per hole were planted and thinned to one seedling per hole at nine days after planting. Supplementary irrigation was delivered via furrows whenever the plants showed water stress conditions and the watering was done only up to field capacity. Supplementary irrigation was done about twice per week during the dry period. Insecticides Confidor® (active ingredient Imidacloprid) and Fastac® (active ingredient Alphacypermethrin) were respectively applied at the rate of 5 ml /20 litres of water to control aphids, leafminers, white flies, thrips and caterpillars. The pesticides were only sprayed whenever pest populations justified control. For the control of bacterial diseases, rust, leaf spots, blights and mildews, 10 ml/20 litres of water of Ortiva® (active ingredient Azoxystrobin) and 50 g/20 litres of water of Sancozeb® (active ingredient Mancozeb) fungicides were sprayed. The plots were kept weed free by regular hand weeding.

Data collection and analysis: The data collected included crop emergence, number of nodules per plant, nodule dry weight, shoot dry weight, pod yield and yield components. Fresh pod yield was sorted into fine and extra fine grades. For each of the parameter, data was subjected to analysis of variance using Genstat Discovery Edition 3 statistical package at 5% probability level. Treatment means were compared using the least significant difference (LSD) test at 5% probability level (Steel and Torrie, 1987).

Determination of the cost of the treatments: For each of the various inorganic fertilizer application regimes the cost of production and revenue accrued from the sale of marketable pods were estimated. The cost of fertilizer and pesticides was determined from quotations of various stockists in Mwea and the cheapest adopted in the calculations. The wholesale price from Monsanto and Kenya Highland Seed Company Ltd respectively, were used since snap bean seed is not distributed by stockists in Mwea. The fixed costs for the various regimes consisted of the cost of labour for application of pesticides, irrigation water and weeding for the entire 10 weeks growing period. The average price paid for extra fine and fine grades by the exporters was Kshs 55.00 and Kshs 25.00 per kg of pods respectively, during the two planting seasons. Net profit was then calculated.

Table 1: Calculation of cost of inputs per hectare (ha)

Input	Quantity	Rate (Kshs)	Total cost (Kshs)
Pesticides:			
Monceren GTFS 390 (insecticide)	8 No x 50 ml	205.00	1,640.00
Fastac (insecticide)	2 No x 50 ml	180.00	450.00
Ortiva (fungicide)	25 No x 50 ml	150.00	3,750.00
Snap bean seed:			
Amy	1 No x 50 kg	700.00	35,000.00
Serengeti	1 No x 50 kg	827.50	41,375.00
Labour:			
For land preparation, ridging, fertilizer application and weeding	3 repeat operations of 35.27 task rates (1 ha=35.27 blocks measuring 283.5 m^2 each/man day task rate) in 10 weeks	375.00	39,678.75
Irrigation:			
Cost of water and labour for application	1 unit	40,000.00	40,000.00
Fertilizers application regime:			
CAN-CAN-CAN	87.4 kg+ 87.4 kg +174.9 kg = 349.7 kg	32.93	11,515.00
. DAP-CAN	240 kg DAP + 180 kg CAN	53.00 + 33.00	18,660.00
DAP-CAN-NPK (17:17:17)	125 kg DAP + 125 kg CAN + 125 kg NPK	53.00 + 33.00 + 46.00	16,500.00
DAP-NPK	240 kg DAP + 276 kg NPK	53.00 + 46.00	25,416.00
Cost of fertilizer regime:			
CAN + labour	11,515.00 + 39,678.75	-	51,193.75
DAP + CAN + labour	18,660.00 + 39,678.75	-	58,338.75
DAP-CAN-NPK + labour	16,500.00 + 39,678.75	-	56,178.75
DAP-NPK + labour	25,416.00 + 39,678.75	-	65,094.75
Control (No fertilizer) + labour	39,678.75	-	39,678.75

RESULTS

In the second season inorganic fertilizer application depressed both nodule numbers and nodule dry weight (Table 2 and 3). Variety Serengeti had higher nodule numbers than Amy in both seasons, but there were no varietal differences with respect to nodule dry weight.

Table 2: Effect of inorganic fertilizer application regimes on number of nodules per plant at flowering stage of snap beans

Fertilizer regime (F)	First Season			Second Season		
	Amy	**Serengeti**	**Means**	**Amy**	**Serengeti**	**Means**
Control	0.59	0.53	0.56	2.05	4.47	3.26
CAN	0.35	1.27	0.81	1.40	2.30	1.85
DAP-CAN	0.26	0.83	0.55	1.87	2.25	2.06
DAP-CAN-NPK	0.31	0.65	0.48	1.62	1.98	1.80
DAP-NPK	0.49	0.63	0.56	1.28	2.25	1.77
Means	0.40	0.78		1.64	2.65	
		$LSD_{P=0.05}$: V= 0.22			$LSD_{P=0.05}$: V= 0.64	
		$LSD_{p=0.05}$: F= NS			$LSD_{p=0.05}$: F= 1.01	
		$LSD_{p=0.05}$: F x V=NS			$LSD_{p=0.05}$: F x V= NS	
		CV % =47.6			CV % = 38.6	

Table 3: Effect of inorganic fertilizer application regimes on the average nodule dry weight (mg/plant) at flowering stage of snap beans (6 weeks after emergence)

Fertilizer regime (F)	First Season			Second Season		
	Amy	**Serengeti**	**Means**	**Amy**	**Serengeti**	**Means**
Control	11.0	11.3	11.2	25.3	48.0	36.7
CAN	4.8	13.0	8.9	14.7	16.0	15.3
DAP-CAN	8.5	13.7	11.9	14.7	23.3	22.3
DAP-CAN-NPK	10.3	22.2	16.2	22.0	22.7	22.3
DAP-NPK	9.2	7.5	8.3	22.7	16.7	19.7
Means	8.8	13.5		19.9	25.3	
		$LSD_{P=0.05}$: V= NS			$LSD_{P=0.05}$: V= NS	
		$LSD_{p=0.05}$: F= NS			$LSD_{p=0.05}$: F= 11.98	
		$LSD_{p=0.05}$: F x V=NS			$LSD_{p=0.05}$: F x V= NS	
		CV % =87.7			CV % = 43.7	

In the first season, variety and inorganic fertilizer application regime had a significant effect on shoot dry weight (Table 4). Variety Serengeti had higher shoot dry weight than Amy. DAP-CAN and DAP-NPK treated plots had higher shoot dry weight than plants in control and DAP-CAN-NPK regimes. In the second season, variety by inorganic fertilizer interaction significantly affected shoot dry weight.

In the first season, variety, inorganic fertilizer application regime and their interaction had significant ($P \leq 0.05$) effects on extra fine yield. Variety Serengeti had significantly higher extra fine pod yield than Amy in all inorganic fertilizer regimes. However, the two varieties were not significantly different in extra fine pod yield in the control plots (Table 5). Fertilizer application regime had no effect on extra fine pod yield in Amy. However, DAP-CAN treated plots significantly out-yielded control and DAP-NPK treated plots in Serengeti.

Table 4: Effect of inorganic fertilizer application regimes on the shoot dry weight (g/m^2) of snap beans (6 weeks after emergence)

Fertilizer regime (F)	First Season			Second Season		
	Amy	**Serengeti**	**Means**	**Amy**	**Serengeti**	**Means**
Control	11.5	18.6	15.1	11.80	25.0	18.4
CAN	19.8	22.2	21.0	22.6	33.5	28.0
DAP-CAN	19.9	36.5	28.2	34.7	46.9	40.8
DAP-CAN-NPK	14.9	17.4	16.2	39.6	31.5	35.6
DAP-NPK	24.9	37.2	31.1	51.5	27.6	39.5
Means	18.2	26.4		32.1	32.9	
		$LSD_{P=0.05}$: V= 7.1			$LSD_{P=0.05}$: V= NS	
		$LSD_{p=0.05}$: F= 11.2			$LSD_{p=0.05}$: F= 13.5	
		$LSD_{p=0.05:}$ F xV=NS			$LSD_{p=0.05:}$ F x V= 19.1	
		CV % =41.5			CV % = 34.3	

Table 5: Effect of inorganic fertilizer application regimes on extra fine pod yield (kg/ha) of snap beans

Fertilizer regime (F)	First season			Second season		
	Amy	**Serengeti**	**Means**	**Amy**	**Serengeti**	**Means**
Control	2294	3005	2650	1450	2935	2193
CAN	2443	5734	4089	1987	3192	2589
DAPCAN	3415	6912	5163	5163	4335	4749
DAPCANNPK	3094	5731	4413	4655	3322	3989
DAPNPK	3348	5198	4278	3989	3351	3667
Means	2919	5316		3448	3427	
	202. $LSD_{P=0.05}$: V= 620.2			$LSD_{P=0.05}$: V= NS		
	203. $LSD_{p=0.05}$: F= 980.6			$LSD_{p=0.05}$: F= NS		
	204.$LSD_{p=0.05:}$FxV=1386.8			$LSD_{p=0.05:}$ F x V=NS		

In the first season variety and inorganic fertilizer application regime interaction had significant ($P<0.05$) effects on fine pod yield (Table 6). The CAN and DAP-CAN-NPK treated plots had significantly higher fine pod yield than control plots in variety Amy while CAN, DAP-CAN, DAP-CAN-NPK and DAP-NPK regimes had significantly higher fine pod yield than the control in Serengeti. DAP-CAN-NPK regimes significantly out-yielded DAP-CAN and DAP-NPK in Amy variety. There were however, no differences in fine pod yield among the inorganic fertilizer treated plots in Serengeti. Variety Serengeti out-yielded Amy (Table 6).

Table 6: Effect of inorganic fertilizer application regimes on fine pod yield (kg/ha) of snap beans

Fertilizer regime(F)	First season			Second season		
	Amy	**Serengeti**	**Means**	**Amy**	**Serengeti**	**Means**
Control	793	1745	1269	670	2015	1342
CAN	2405	3529	2967	638	2237	1434
DAPCAN	1457	4563	3010	1234	2742	1988
DAPCANNPK	3102	3827	3464	1149	2777	1963
DAPNPK	1196	3919	2558	1044	3275	2159
220.Means	1791	3517		947	2609	
	$LSD_{P=0.05}$: V=537.8			$LSD_{P=0.05}$: V= 641.4		
	$LSD_{p=0.05}$: F= 850.4			$LSD_{p=0.05}$: F= NS		
	$LSD_{p=0.05:}$FxV=1202.6			$LSD_{p=0.05:}$ F x V=NS		

In the first season, variety and inorganic fertilizer application regime interaction had significant P≤0.05) effects on total pod yield (Table 7). Variety Serengeti had significantly higher total yield than Amy. The DAP-CAN-NPK inorganic fertilizer application regime had a significantly higher total pod yield than the control in Amy. The DAP-CAN fertilizer application regime had significantly higher total pod yield than DAP-NPK and control in variety Serengeti.

Table 7: Effect of inorganic fertilizer application regimes on total pod yield (kg/ha) of snap beans

Fertilizer regime(F)	First season			Second season		
	Amy	**Serengeti**	**Means**	**Amy**	**Serengeti**	**Means**
Control	3351	5001	4176	2898	6460	4679
CAN	5065	9726	7395	3154	6761	4957
DAPCAN	5100	11748	8424	7780	8756	8268
DAPCANNPK	6357	9825	8091	6761	7340	7051
DAPNPK	4763	9530	7146	6216	8211	7214
Means	4927	9166		5362	7506	
	$LSD_{P=0.05}$: V= 963.7			$LSD_{P=0.05}$: V=2123.7		
	$LSD_{p=0.05}$: F= 1523.7			$LSD_{p=0.05}$: F= NS		
	$LSD_{p=0.05}$:FxV=2154.8			$LSD_{p=0.05}$: F x V=NS		

During the first season, DAP-CAN and DAP-CAN-NPK fertilizer treatments on Amy plots had 8.5% and 40% higher net profit respectively, than the average for all the treatments while CAN and DAP-NPK treated plots had 20% and 12% lower net profit respectively. DAP-NPK inorganic fertilizer application on Serengeti plots is the only regime that had a 5.2% lower net profit than the average of all the treatments on Serengeti plots. DAP-CAN fertilizer application on Serengeti plots had the highest net profit of 40.7% and 344.1% relative to the average profit for all treatments on Serengeti and Amy, respectively (Table 8). During the second planting, CAN fertilizer application on variety Amy plots was the only regime that had a 92% lower net profit than the average net profit for all the fertilizer application treatment on Amy plots. DAP-CAN had a 34% higher net profit than the average of all fertilizer application regimes on variety Serengeti plots (Table 8).

Table 8: Effect of inorganic fertilizer application regimes on average profit/ha (Kshs) of snap beans

(First season planting)

Variety	**Fertilizer**	**Extra fine (kg/ha)**	**Fine (kg/ha)**	**Income (Kshs./ha)**	**Cost (Kshs./ha)**	**Profit (Kshs./ha)**
Amy	CAN	2443	2405	194490	132034	62456
Amy	DAPCAN	3414	1456	224170	139179	84991
Amy	DAPCANNPK	3081	3101	246980	137019	109961
Amy	DAPNPK	3348	1196	214040	145935	68105
Amy	CONTROL	2306	793	146655	80840	65815
Serengeti	CAN	5733	3529	403540	138409	265131
Serengeti	DAPCAN	6892	4562	493133	145554	347579
Serengeti	DAPCANNPK	5721	3827	410330	143394	266936
Serengeti	DAPNPK	5242	3919	386285	152310	233975
Serengeti	CONTROL	3005	1745	208900	87215	121685

(Second season planting)

Variety	**Fertilizer**	**Extra fine (kg/ha)**	**Fine (kg/ha**	**Income (Kshs/ha)**	**Cost (Kshs/ha)**	**Profit (Kshs/ha)**
Amy	CAN	1987	638	125204	132034	-6830

Amy	DAP-CAN	5163	1234	314826	139179	175647
Amy	DAP-CAN-NPK	4655	1149	284759	137019	147740
Amy	DAP-NPK	3983	1044	245140	145935	99205
Amy	CONTROL	1450	670	96501	80840	15661
Serengeti	CAN	3192	2237	231511	138409	93103
Serengeti	DAP-CAN	4335	2742	306957	145554	161403
Serengeti	DAP-CAN-NPK	3322	2777	252153	143394	108759
Serengeti	DAP-NPK	3351	3275	266179	152310	113869
Serengeti	CONTROL	2935	2015	211800	87215	124585

DISCUSSION

Application of inorganic fertilizer depressed nodule numbers and nodule dry weight. In previous studies inhibitory effects of added nitrogen on nodulation have been reported in beans (e.g. Chemining'wa *et al*., 2007 and Otieno *et al*, 2009). DAP-CAN and DAP-NPK inorganic fertilizer application regimes increased shoot dry weight Phosphorus fertilizer contributes to early crop development and maturity (Tantawy *et al*., 2009), while nitrogen is required for dry matter production in crops. Previous studies have shown increases in vegetative growth of snap beans and dry beans on addition of N-fertilizer (Adbel-Mawgoud *et al*., 2005; Otieno *et al*., 2009). Variety Serengeti had higher pod yields than Amy in both first and second season. Varieties differed in their response to fertilizer application with respect to extra fine pod yield where Amy did not respond to fertilizer application in terms of extra fine grade. Total pod yield as well as pod quality of snap beans were significantly enhanced with increased levels of nitrogen (Mahmoud *et al*, 2010). DAP-CAN applied on variety Serengeti had higher extra fine yield than the control. This is in agreement with studies done on snap bean which indicated that increasing NPK rates or increasing N: P fertilizer levels increased yield of green beans (Abdel-Mawgoud *et al*., 2005). Application of 91 kg N/ha asDAP-CAN on Serengeti had the highest total pod yield and profit margin, compared to CAN, DAP-CAN-NPK and DAP-NPK regimes. Similar results were obtained by Hedge and Srinivas (2004) in which application of N-fertilizer at 100kg/ha to the vegetable green beans led to high marketable yield of all varieties. That DAP-CAN, DAP- CAN-NPK and DAP-NPK regimes significantly out-yielded CAN alone regime suggests that P is still limiting in Mwea soils. This can be attributed to the fact that the soil pH in Mwea is low. And therefore may lead to P fixation making it less available for plant uptake. The authors have not explained why Serengeti (The lack of extra fine yield response to treatments in the second season can be attributed to poor weather, hence poor crop. The poor crop led to reduced frequency of harvesting resulting in development of extra fine pods) performed poorly during the 2nd planting (2919 for Amy and 5316 kg/ha for Serengeti during the 1st planting vs. 3448 and 3427 for Amy and Serengeti during the 2nd planting yet the same performance trend was maintained for the two varieties with regard to fine pod weight).

CONCLUSION AND RECOMMENDATIONS

From the results of this study, it is concluded that snap bean variety Serengeti out performs Amy in terms of overall growth and yield. Application of DAP-CAN on Serengeti had vigorous plants in terms of overall growth, increased extra fine and fine pod yield of snap bean than CAN and DAP-NPK regimes. The cumulative net profit of the various regimes in this study indicated that DAP-CAN applied to variety Amy and Serengeti offered a higher return to the farmer. Planting of Serengeti with DAP-CAN regime is recommended for farmers in Mwea based on yields and economic analysis.

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