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# Performance of a local open pollinated maize variety and a common hybrid variety under intensive small-scale farming practices

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Given that the majority of maize farmers in Kenya are small-scale, improvement in maize production must focus on increased production per unit area. While hybrid maize varieties outperform local open pollinated varieties under conventional farming practices, their relative performance has not been tested under small-scale intensive production practices. A study was conducted in Kitale, western Kenya, to evaluate performance of 'Namba Nane'; a local open pollinated maize variety, alongside a high yielding hybrid, 'Hybrid 614D' under a small-scale, intensive farming practice that utilizes deep tillage and compost/manure. Each variety was subjected to conventional and diagonal offset close spacing. The grain yield of the hybrid (12.8 tons ha<sup>-1</sup>) was not statistically different from that of 'Namba Nane' (10.2 tons ha<sup>-1</sup>), even though the number of rows per cob and number of ears per plant of the former were significantly greater than those of latter. However, yields of both varieties were about twice the published potential yield of improved hybrid maize (6 tons ha<sup>-1</sup>) grown with conventional practices. Seed kernels of 'Namba Nane' weighed 1.6 times more than those of 'Hybrid 614D'. Diagonal off-set close spacing under this technology increased the maize grain yield of both varieties 1.3 times. The cost of producing 'Namba Nane' under the technology was significantly less than producing the hybrid and twice more profitable (gross margin). Growing 'Namba Nane' using small-scale, intensive farming practices may be a viable option for most small-scale, resource-challenged farmers to increase economic yields.

**Key words:** Biointensive, double digging, hybrid, open pollinated, 'Namba Nane', small-scale intensive.

## INTRODUCTION

While maize is the most important cereal crop in Kenya, where it serves as both a staple food and cash crop for millions of people (Ojiem et al., 1996; Vanlauwe et al.,

2008), increases in its productivity have not kept pace with increasing demand. High population pressure and repeated subdivision of land, coupled with limited

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resources available to the large proportion of the population living below the poverty index, severely constrain maize production. Kenya's population continues to increase at an average of 2.6% annually since 2002 and stood at 41.6 million in 2011 (World Bank, 2012). Average farm sizes are shrinking largely due to the traditional land inheritance practice of subdividing land among male offspring (Kilson, 1955; Karanja, 1991; Yamano, 2007; Shreffler and Nii-Amoo, 2009). Decreasing farm sizes coupled with increasing population drives a deficit spiral in which yields decrease because farmers can afford fewer and fewer inputs (Ojiem et al., 1996; Macharia et al., 2010). Part of the solution to this challenge lies in very small scale, high yielding, low-external-input farming practices (Ojiem et al., 1996; Omondi, 1996; Jeavons, 2012).

Although most farmers in Kenya recognize that modern maize hybrids generally yield more than local open pollinated varieties [OPVs (Ojiem et al., 1996; Duvick et al., 2004; Kutka, 2005; Macharia et al., 2010)], they believe that hybrid maize can perform well only under high input management practices (Ojiem et al., 1996; Macharia et al., 2010). The high cost of certified seed and fertilizer forces the majority of farmers in Kenya to either use low-yielding farm saved seeds, derived from local varieties and hybrids, and/or apply fertilizers below the recommended rates (Ojiem et al., 1996; Macharia et al., 2010). Alternative methods of farming are needed to intensify maize productivity.

For decades, maize production recommendations have tended to focus more on yield than profit, in a bid to encourage more farmers to adopt high-yielding hybrids and high-input management (Shull, 1911). This emphasis has, however, not always been successful in helping farmers to meet their economic, environmental or lifestyle needs (Brummer, 2004; Kirschenmann, 2004). Studies have shown that with little or no input of synthetic fertilizers, grain yield of OPV maize cultivars can be comparable or better than that of hybrids (Ojiem et al., 1996; Coulter et al., 2010). However, performance of local OPVs using high-yielding, small-scale, intensive farming practices has not been documented. Such practices are promoted by development organizations and often include high rates of compost, dense crop spacing, deep subsoil loosening, and other labor-intensive practices intended to produce very high yields on very small plots. Deep soil preparation (often called double digging) can increase porosity and aeration of the soil, which, combined with high rates of compost, stimulates microbial activity, root penetration, and enhanced water and nutrient supply potential (Chaudhary et al., 1985; Varsa et al., 1997; Jeavons, 2012). This allows high-density planting that can lead to very high yields on small areas.

The objective of this study was to compare the agronomic and economic performance of an indigenous OPV called 'Namba Nane' with that of a popular high

yielding hybrid (Hybrid 614D) under intensive small-scale farming practices. Results could aid farmers- and agricultural development workers in helping farmers choose the most economically beneficial maize varieties for use with small-scale, intensive farming practices.

## MATERIALS AND METHODS

A field study was established in 2013 at Manor House Agricultural Centre (MHAC) near Kitale town in Trans Nzoia County, western Kenya (01°00'N, 34°55'W; elevation, 1,860 m above sea level) to evaluate the performance of 'Namba Nane', under small-scale intensive farming techniques, compared to that of 'Hybrid 614D'. With mean annual rainfall of 1200 mm, Trans Nzoia experiences a bimodal rainfall pattern, with the long rains starting from mid-March to June and short rains from August to November (Jaetzold and Schmidt, 1983). Temperature ranges from an average minimum of 10°C to a maximum of 27°C (Jaetzold and Schmidt, 1983). The soils in the study site were deep, well-drained, Ferralsols (Jaetzold and Schmidt, 1983; Food and Agriculture Organization, 1988). For this study, components of a farming system known as Bio-intensive agriculture (BIA) that combines deep soil preparation, high rates of compost, and high-density planting were used. Developed by John Jeavons of Ecology Action, Willits, California, U.S.A., BIA is a combination of *French Intensive Techniques* and *Biodynamic Techniques* practiced in Europe in 1800s and early 1900s. It utilizes deep soil preparation (double digging) to 60 cm depth, composting at rates exceeding 60 Mg ha<sup>-1</sup>, diagonal offset close spacing, companion planting, and biological pest control (Jeavons, 2012).

The study was a two-factor factorial randomized complete block design replicated four times. The first factor consisted of maize varieties and included two levels: 'Hybrid 614D' obtained from Kenya Seed Company Ltd., and a traditional OPV called 'Namba Nane' obtained from previous season's crop grown at the MHAC's Central garden. 'Namba Nane' is a Kiswahili phrase meaning "number eight", referring to the number of rows of kernels commonly produced on a cob. The second factor consisted of planting densities and included two levels: conventional spacing recommended by the Kenya Ministry of Agriculture of 75 cm between rows and 30 cm within the row (6 plants m<sup>-2</sup>); and BIA-recommended diagonal offset spacing of 38 cm between plants (9 plants m<sup>-2</sup>; Jeavons, 2012). The two factors were subjected to BIA double digging and composting practices, as described by Jeavons (2012) across the treatments.

All 12 plots (measuring 1.5 × 6 m) were double dug on 25<sup>th</sup> March, 2013, after which 60 kg of composted farm yard manure from the Ol'ngantongo Agricultural Development Corporation farm were incorporated into each plot to a depth of 10 cm (66.7 t ha<sup>-1</sup>, dry weight). Plots were planted by hand on 8<sup>th</sup> April, 2013. Two seeds were planted per hole and then plants were thinned to one per hole two weeks after seed emergence, resulting in a plant population of 60 and 78 plants per plot in conventional and diagonal offset spacing respectively. Plots were weeded on 9<sup>th</sup> May and 13<sup>th</sup> June, 2013.

Yield data was determined by harvesting maize plants from an area of 2 m<sup>2</sup> from the middle row of each plot on 26<sup>th</sup> September, 2013. Determination of grain yield was done after maize grains were sundried to a moisture content of 13%. Dry weight of stover and cobs from the harvested samples was also recorded to determine biomass yield. Plant growth was measured as height, leaf length and width as well as leaf population plant<sup>-1</sup> done at 8 leaf stage and tasseling. Data were analysed using the MIXED procedure in SAS version 9.2 (SAS Institute, 2008). Differences in treatment means were determined using Fisher's protected LSD ( $\alpha=0.05$ ).

**Table 1.** Cost of various inputs in Kenya shillings (KES) per deep tilled plot (9 m<sup>2</sup>) for maize variety 'Namba Nane' (No. 8) and 'Hybrid 614D' at MHAC near Kitale, Kenya, 2013.

Breed	Spacing	Seed	Tilling	Fertilizing	Planting	Harvesting	Drying and threshing
	cm	Labor					
		KES/9m <sup>2</sup> plot					
Namba Nane	75 by 30	1.7	90	79	5.4	5	20
Namba Nane	38 by 38	1.8	90	79	10	5	22
Hybrid 614D	75 by 30	4.0	90	79	5.4	5	18
Hybrid 614D	38 by 38	4.3	90	79	10	5	20

### Economic analysis

Economic analysis of maize from different treatments was determined using gross margin and cost-benefit analyses. Cost and benefit estimates were based on revenues and costs incurred in production of maize using the different treatments. Total revenue represented the value of maize harvested from each plot based on prevailing prices at the time of the study. The price of 2.5 kg of 'Namba Nane' at the Kitale Municipal Market and 'Hybrid 614D' from Kenya Seed Company Ltd. were KES 100 (about U.S. \$1.20) and KES 425 (about U.S. \$5.20), respectively, in the month of October 2013. Variable costs accrued from purchase of seeds and labor involved in land preparation (double digging), planting, gapping, thinning, weeding, harvesting, drying and shelling were determined based on the prevailing market prices (Table 1). Benefit/cost ratio was determined by dividing the revenue by variable costs from each treatment, while gross margin was obtained from revenue less variable cost accrued in each treatment. Values of costs, revenue, gross margin, and benefit/cost ratio were subjected to analysis of variance using the MIXED procedure in SAS version 9.2 (SAS Institute, 2008) and treatment differences determined using Fisher's protected LSD ( $\alpha = 0.05$ ).

## RESULTS

### Agronomic analysis

There was no maize variety by plant spacing interaction for kernel rows per cob, grain yield, the weight of 100 kernels, and number of cobs per plant (Table 2), thus data for maize variety and plant spacing for those agronomic yield parameters were combined for analysis. 'Hybrid 614D' had significantly more ( $P < 0.0001$ ) kernel rows per cob than 'Namba Nane' (Table 3). Mean number of rows per cob of hybrid was 13 compared to 8.7 for 'Namba Nane.' Plant spacing had no effect on the number of rows per cob. 'Hybrid 614D' had significantly more ( $P = 0.050$ ) number of cobs per plant than 'Namba Nane' (Table 3).

There were no differences between treatments for maize biomass yield. There were also no significant differences between the two varieties for maize grain yield (Table 3). However, maize grown at the greater density (BIA off-set spacing) had significantly greater ( $P = 0.035$ ) grain yield than maize grown at the lower plant density [conventional spacing (Table 3)]. While plant density had no significant effect on the weight of maize

kernels, 'Namba Nane' had highly significant ( $P < 0.0001$ ) greater 100 – kernel weight of maize than the hybrid (Table 3). Plant height, leaf length, leaf width, and leaf population were not affected by maize variety or plant spacing.

### Economic analysis

There was a significant ( $P < 0.0001$ ) variety by spacing interaction for cost of growing maize, thus data for this parameter were analyzed separately by variety and plant density (Table 4). Results revealed that the variable cost of growing 'Hybrid 614D' was significantly ( $P < 0.0001$ ) greater than growing 'Namba Nane' at each plant spacing whereby growing the hybrid under close spacing cost the most and growing the OPV under conventional spacing cost the least (Table 5).

There was no significant interaction between variety and plant spacing for revenue, gross margin, and benefit/cost ratio (Table 4) thus data for variety and spacing for those economic parameters were combined for analysis. While the numerical value of revenue, gross margin, and benefit/cost ratio for 'Namba Nane' were greater than the hybrid, these differences were only marginally significant [ $P = 0.10, 0.095, \text{ and } 0.089$  respectively (Table 6)]. However, all three economic parameters were significantly greater at the closer BIA spacing (greater plant density) than the conventional spacing (lower plant density) [ $P = 0.041, 0.054, \text{ and } 0.54$  respectively (Table 6)].

## DISCUSSION

While results from this study revealing that the grain yield of maize variety 'Hybrid 614D' was 2.6 tons ha<sup>-1</sup> greater than that of 'Namba Nane' were expected (Duvick et al., 2004; Kutka, 2005; Macharia et al., 2010), these differences were not statistically significant (Table 3). More instructive, however, were findings that the grain yield of 'Hybrid 614D' and 'Namba Nane' were double and 1.7 times greater, respectively, than the documented potential of 6 tons ha<sup>-1</sup> of improved hybrid maize planted with adequate inorganic fertilizers under conventional

**Table 2.** Partial analysis of variance ( $P > F$ ) values for maize kernel rows per cob, grain yield, and 100 kernel weight of maize at MHAC near Kitale, Kenya, 2013.

Source of variation	df	Rows per cob	Yield	Weight of 100 kernels	No. of cobs per plant
Variety	1	**	NS	**	*
Spacing	1	NS	*	NS	NS
Variety*Spacing	1	NS	NS	NS	NS

\*Statistical significance at 0.05 probability level, \*\*Statistical significance at 0.001 probability level, NS Denotes not significant.

**Table 3.** Mean kernel rows per cob, yield, 100 kernel weight, and number of ears per plant of 'Hybrid 614D' and 'Namba Nane' at MHAC near Kitale, Kenya, 2013.

Maize variety	Rows per cob	Yield	Weight of 100 kernels	Cobs per plant
	Value	Tons/ha	Grams	Value
Namba Nane	8.71 <sup>b</sup>	12.80 <sup>a</sup>	57.61 <sup>a</sup>	1.01 <sup>b</sup>
Hybrid 614D	13.19 <sup>a</sup>	10.21 <sup>a</sup>	36.97 <sup>b</sup>	1.15 <sup>a</sup>
<i>P Value</i>	<0.0001	NS	<0.0001	0.050
<b>Spacing (cm)</b>				
38 by 38	10.83 <sup>A</sup>	13.18 <sup>A</sup>	47.63 <sup>A</sup>	1.05 <sup>A</sup>
75 by 30	11.08 <sup>A</sup>	9.83 <sup>B</sup>	46.95 <sup>A</sup>	1.11 <sup>A</sup>
<i>P Value</i>	NS	0.035	NS	NS

Means within a column followed by the same letter are not significantly different (LSD,  $\alpha = 0.05$ ).

**Table 4.** Partial analysis of variance ( $P > F$ ) values for economic parameters of growing maize at MHAC near Kitale, Kenya, 2013.

Source of variation	df	Cost	Revenue	Gross margin	Benefit/Cost
Variety	1	***	*	*	*
Spacing	1	***	**	**	**
Variety*Spacing	1	***	NS	NS	NS

\*Statistical significance at 0.10 probability level, \*\*Statistical significance at 0.05 probability level, \*\*\*Statistical significance at 0.0001 probability level, NS denotes not significant.

**Table 5.** Mean cost of growing 'Hybrid 614D' and 'Number 8' on a 9 m<sup>2</sup> plot using intensive farming methods at MHAC near Kitale, Kenya, 2013.

Maize variety	Spacing	Cost
		KES/9m <sup>2</sup> plot
Hybrid 614D	38 by 38	229 <sup>a</sup>
Namba Nane	38 by 38	224 <sup>b</sup>
Hybrid 614D	75 by 30	221 <sup>c</sup>
Namba Nane	75 by 30	217 <sup>d</sup>
<i>P Value</i>		<0.0001

Means within a column followed by the same letter are not significantly different (LSD,  $\alpha = 0.05$ ).

revealing that close spacing for both varieties yielded significantly more maize grain yield than conventionally spaced plants (Table 3), conform with observations by Jeavons (2012) that techniques that combine deep tillage, compost application, and high-density planting can increase the yield of crops per unit of land 2 to 6 times compared with the conventional average. The soil tilth obtained by double digging can allow plant roots to penetrate downwards rather than spread outwards, enabling high-density planting (Jeavons, 2012). These results are also in agreement with Chaudhary et al. (1985) who found that sub-soiling and deep digging to a depth of 45 cm increased maize plant heights by 30 to 35 cm and maize grain yield by 70 to 350% compared with maize grown under conventional tillage practices. Similar results were obtained by Varsa et al. (1997) who found that deep tillage to a depth of 60 to 90 cm resulted in increased maize grain yield by up to 47% compared to

agricultural methods in the high potential areas of Kenya (Kipsat et al., 2004). These findings, in addition to those

**Table 6.** A comparison of revenue, gross margin, and benefit/cost ratio of growing 'Hybrid 614D' and 'Namba 8' using low cost BIA techniques at two different plant spacing at MHAC near Kitale, Kenya, 2013.

Maize variety	Revenue	Gross margin	Benefit/Cost ratio
	KES/9m <sup>2</sup> plot		
Namba Nane	367.7 <sup>a</sup>	147.2 <sup>a</sup>	1.67 <sup>a</sup>
Hybrid 614D	294.5 <sup>b</sup>	69.68 <sup>b</sup>	1.31 <sup>b</sup>
<i>P value</i>	0.11	0.095	0.089
<b>Spacing (cm)</b>			
38 by 38	380.2 <sup>A</sup>	154.15 <sup>A</sup>	1.69 <sup>A</sup>
75 by 30	282.0 <sup>B</sup>	62.73 <sup>B</sup>	1.28 <sup>B</sup>
<i>P Value</i>	0.041	0.054	0.054

Means within a column followed by the same letter are not significantly different (LSD,  $\alpha = 0.05$ ).

tillage to a depth of 40 cm. The greatest increase in maize grain yield in deeply tilled soil was achieved in the year that received the least rainfall, suggesting that maize roots extracted moisture from greater depths as the depth of soil tillage increased (Varsa et al., 1997). Studies by Chaudhary et al. (1985) showed that sub-soiling and deep digging to a depth of 45 cm decreased the soil penetration resistance in the 20 to 40 cm layer to one-tenth that of conventionally plowed soil and resulted in deeper and greater rooting of maize plants. Similar results were obtained by Varsa et al. (1997) who found that deep tillage to a depth of 60 to 90 cm reduced soil bulk density, increased root proliferation, and rooting depth. Deep tillage can also break the compacted hard pan that often occurs below the plow layer where mouldboard plows are used (Vepraskas et al., 1995; Joubert and Labuschagne, 1998). Absence of significant differences in grain yield between 'Hybrid 614D' and 'Namba Nane', in spite of the hybrid having significantly greater number of kernel rows per cob and greater number of cobs per plant may partly be explained by our findings that 'Namba Nane' had significantly greater kernel weight compared to the hybrid (Table 3). These findings suggest that 'Namba Nane' may be more resource efficient than the hybrid. It is important to note that most commercial maize hybrids are developed under high nitrogen levels and fertile soils found in research stations (Muza et al., 2004), and are therefore expected to utilize nutrients more luxuriously. Most traditional OPVs were developed under conditions of low and more dispersed nutrient concentrations prevalent in more marginal regions with less fertile soils in many developing countries (Ojiem et al., 1996; Duvick et al., 2004; Macharia et al., 2010; Gudu et al., 2005; Denning et al., 2009). 'Namba Nane' plants may have invested resources to seed formation more efficiently compared to the hybrid. This is an important attribute, especially for the more resource challenged farmers in many rural areas of Africa.

While 'Namba Nane' is generally known to produce yields that are comparable with the newer improved hybrids under reduced fertilizer input (Ojiem et al., 1996), many farmers have gradually stopped growing it and/or saving seed from it. Agricultural modernization and corporate consolidation of agriculture have generally disincentivized farmers to save their local seeds such that farmers increasingly prefer purchased seed (Lewis and Mulvany, 1997; Foti et al., 2008; Connolly, 2011). As purchased seed replaces older heirloom varieties, availability of these varieties in many farming communities declines (Lewis and Mulvany, 1997). As a result, many of the available heirloom maize seed varieties no longer maintain their original purity – hence the difficulty of obtaining 'Namba Nane' seeds that produce uniform eight kernel rows per cob. This may partly explain why results from this study revealed that average kernel rows per cob of 'Namba Nane' were 8.7.

Our results revealed that it cost significantly more to grow 'Hybrid 614D' than 'Namba Nane' using this small-scale intensive production technology (Table 5), while the revenue, gross margin, and benefit/cost ratio tended to be greater for 'Namba Nane'. Furthermore, the revenue, gross margin, and benefit/cost ratio were significantly greater for growing both varieties at diagonal offset close spacing (greater BIA plant density) than conventional plant spacing (lower plant density) (Table 6). These results indicate that growing 'Namba Nane' with small-scale, intensive production practices may be a viable option for many smallholder farmers in sub-Saharan Africa to improve yields and profitability. Resource challenged small-scale farmers who cannot afford the high cost of hybrid maize seed and accompanying recommended fertilizer rates, but have parcels of land so small that they would not be daunted by the prospect of double digging or applying compost/manure, may benefit by planting 'Namba Nane' OPV and saving seed for subsequent plantings.

Further work should evaluate the performance of

'Nambe Nane' on different soil conditions and using a range of farming practices. This should include an assessment of the effects and interactions of sub-soiling (double digging), high compost (or farm yard manure) rates, high inorganic fertilizer rates and high density on the grain and biomass yield of 'Namba Nane'.

### Conflict of Interest

The author(s) have not declared any conflict of interests.

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