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Profitability of Improved versus Traditional Cultivation Practices for African Indigenous Vegetables

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Abstract: Vegetables are important for nutrition and income of rural and urban households. However, vegetable consumption in Uganda is below World Health Organization (WHO) recommended guidelines, partly due to low production. The persistent low production arises from poor cultivation methods, low soil fertility, poor quality seed, pests and diseases, among others. This study compared the profitability of improved cultivation methods for African indigenous vegetables (AIVs), i.e., pure stand and in lines, versus traditional practice (mixing seeds of different AIVs then broadcast), both for leafy and seed production. The AIVs included: Nakati (*Solanum aethiopicum* L.), Bugga (*Amaranthus blitum* L.) and Jobyo (*Gynadropsis gynandra* L.), arranged in completely randomized (CR) design with three replicates. Results showed that Nakati was more profitable when grown for leafy compared to seed production with benefit: cost ratio (BCR) 9.2 and 4.0 for leafy and seed, respectively. Bugga for seed was more profitable compared to leafy production (BCR 18.0 and 2.7 for seed and leafy, respectively). Growing Jobyo for seed was more profitable than leafy production (BCR 14.9, 2.4 for seed and leafy, respectively). Growing indigenous vegetables (IVs) for seed in mixed broadcast system, out of the three IVs farmers stand to economically maximize benefits for one crop (BCR 0.9, 1.7 and 10.2 for Bugga, Nakati and Jobyo, respectively) compared to pure stand and in lines (BCR 18.0, 4.2 and 14.9 for Bugga, Nakati and Jobyo, respectively). Thus, famers stand to benefit more if they grow IVs as pure stand and in lines as opposed to mixed and broadcast, whether for leafy or seed production.

Key words: Indigenous vegetables, intensification, benefit-cost ratio, profitability, vegetable seed.

1. Introduction

African indigenous vegetables (AIVs) are an important source of food, nutrition and income for many communities in sub Saharan Africa (SSA). They provide proteins, fibre, vitamins A, C and E, micronutrients including: iron, calcium, magnesium and anti-oxidants that are required for normal growth and health [1]. They also improve palatability and add variety to diets, especially for the poor. Despite their importance, AIVs have not been prioritised in national programmes compared to cash crops and consequently limited resources have been allocated to promote their production and consumption in SSA [2]. As a result, there are limited data on the production levels of specific AIVs. There is therefore a dire need for more studies in SSA to generate critical information on AIVs as increasing global attention is turned towards mobilizing local biodiversity for food security and health [3].

The Food and Agriculture Organization (FAO) and World Health Organization (WHO) [4] developed a joint framework for promoting increased production, availability, access and consumption of fruits and vegetables. This framework guides the development of effective, cost-efficient interventions for promotion of adequate consumption of fruits and vegetables at national and sub-national level [4]. In Uganda, the per capita consumption of African leafy vegetables was estimated as 160 g [5, 6], which is below the

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FAO/WHO recommended value of 400 g [7]. With the world population projected to increase particularly in developing countries and more so in urban areas, there is growing need for farmers to intensify and diversity food production. This is even more challenging in view of combined effects of climate change and growing completion for resources such as land and water [8].

Most traditional vegetable varieties mature much faster than non-native crops, so they could be promising options if the rainy seasons become more erratic. Therefore, their inclusion into the cropping system could be an adaptation measure to a predicted low rainfall season. In addition, despite intensive labour, production of AIVs requires generally low level of investment in terms of capital and inputs. This makes it relatively easy for resource poor farmers (especially women) to grow them in backyards in intercrop with other crops. In addition, market prices for AIVs are usually low, and this makes them accessible to the poor. Intensification and diversification of production systems to include indigenous vegetables (IVs) could therefore go a long way in meeting the increased demand for food and nutrition security.

With major changes in agricultural systems towards market-driven, higher-value, modern supply chains [9], there is increasing shift towards strategies that enhance agricultural diversification and increase the added value of agricultural production [10]. According to Irungu [11] there is increasing awareness of the importance and demand for AIVs among the rural and urban populations, with some AIVs recently finding their way in supermarkets. Indeed, agricultural sectors in many countries are increasingly diversifying into vegetables and fruits, spices, aquaculture products and non-food products [12].

In order for smallholder farmers to benefit from the emerging opportunities that these changes offer, there is increased need for agricultural intensification. For the case of AIVs, this may be achieved through promoting access to better quality seed [13] as well as adoption of technological innovations and practices that will improve vegetable cultivation and thus enhance farm productivity and profitability [12].

The three common leafy IVs grown in central Uganda include: Nakati (*Solanum aethiopicum* L.), Bugga (*Amaranthus blitum* L.) and Jobyo (*Gynadropsis gynandra* L.). Traditionally farmers in central Uganda grow these species as mixed seeds and broadcast on the same piece of land [14]. This practice presents some advantages in terms of reduced costs of production, increased productivity of land [15] and also acts as an insurance against losses due to changing climatic conditions [16]. In addition, since these IVs mature at different times, a farmer first harvests Bugga, then Jobyo, followed by Nakati, a farmer is able to get a diversity of vegetables over a somewhat longer period. Notsi [16] urged that African indigenous farming methods as opposed to conventional farming methods for the cultivation of AIVs are cost effective, environmentally friendly and sustainable. However, it is not clear whether the traditional cultivation system for IVs as practiced in central Uganda, is as profitable as the modern system which advocates for planting each of the species as pure stand and in lines.

The objective of this study was to compare the profitability of improved cultivation methods for IVs, i.e., pure stand and in lines, versus traditional practice (mixing seeds of different IVs then broadcast). This was done for leafy or seed vegetable production. The study would therefore generate important information to contribute towards intensification and profitability of IV production for increased productivity to meet the growing demand for IVs.

2. Materials and Methods

2.1 Field Methods

Experiments were set up for two seasons during 2017 to evaluate different methods of producing three AIVs, i.e., Nakati (*S. aethiopicum* L.), Bugga (*A. blitum* L.) and Jobyo *(G. gynandra* L.) for both leafy

and seed production. The study was sited on-station at National Agricultural Research Laboratories Institute (NARL) in Kawanda, National Crops Resources Research Institute (NaCRRI) in Namulonge, and Mukono Zonal Agricultural Research and Development Institute (MUZARDI). The NARL and NaCRRI are located in Wakiso district while MUZARDI is found in Mukono district, all in central Uganda.

The trials evaluated planting IVs as pure stand and in rows, versus farmers' practice of mixing different vegetable seeds then broadcasting them at planting. Treatments included: Nakati, Jobyo and Bugga planted in rows at 10 cm spacing versus a farmer practice (mixing all three vegetable seeds then broadcasting them). The four treatments were randomly allocated onto 16 m^2 plots, each plot separated by 0.6 m row. The experimental design was completely randomized, replicated three times. Manure from layer chicken was applied at 5 t/ha. In row planting, manure was applied within rows before planting seeds in the same lines. However, in broadcasting, manure was broadcast within each plot, thereafter seed followed. The same arrangement was set up for leafy as well as seed vegetable production.

The same experiment was also established on-farm with three farmer groups: Kyamutakasa and Mifunya in Nakaseke district and Namulonge Horticulture famers group in Wakiso district, both in central Uganda. This was to demonstrate to farmers and trainers (80 farmers, two farmer trainers and two extension officers) improved vegetable cultivation techniques for both leafy and seed production. Wakiso, Mukono and Nakaseke districts lie within the Lake Victoria crescent agro-ecological zone (AEZ) in central Uganda, located 1,200 m above sea level (asl), with a temperature range of 15-30 °C and a moderate soil fertility. The area receives 1,200-1,450 mm of rainfall, bi-modal, from March to May with peak in April, and a second season from August to November with a modest peak in October/November [17]. Crop management included regular weeding, thinning and spraying. Harvesting for leafy vegetable was done piecemeal until the crop in the plot was over. Harvesting for seed was taken when fruits were ripe. The harvested produce was valued at farm gate price for both leafy and seed production.

2.2 Profitability Analysis of IV Farming Methods

2.2.1 Production Costs

The total production costs are the sum of fixed and variable costs [18]. For this experiment, however, land and farm tools rental field cost were considered, i.e., hiring land hectare per year, farm tools (depreciation) for spray pump (20 L), watering cans (5), hoes (6) and weighing scale (1). Cost of transporting inputs to, and outputs from trial sites were not included in the gross margin because output was sold at farm gates hence no extra cost of transportation.

Differences in labour prices, quantity of inputs used, price for inputs, purpose for growing vegetables (either for seed or leafy production) among other factors, caused variations in production costs from one farmer group to another. Variable costs of vegetable production were organized in the order of pre-harvest and post-harvest costs. Pre-harvest costs included labour and all the inputs directly related to the production practice, i.e., land preparation, field marking, fertilizer application, planting, weeding, pest and disease control, thinning, seeds and fertilizers. Harvest costs included labour cost of picking fruits, processing and marketing.

2.2.2 Revenue Information

The famers with the guidance from the research team recorded the total harvest from the 16 m^2 plot for both leafy and seed production experimental plots for the three IVs under different field agronomic practices within each of the three districts. The leafy vegetable harvested was marketed at farm gate by traders from nearby markets and income recorded. However, for seed the farmer groups were linked to seed companies with whom they entered into trade agreements specifying the price per kilogram of seed. This

information was used in computing gross margins and net income. The total harvest for both leafy and seed vegetable from a 16 m^2 plot was extrapolated to hectare basis. The total yield was then multiplied by price per kilogram of seed to get gross income per hectare in Uganda shillings. The gross margin accrued from the use of different practices was determined by the difference between the gross production value and the cost incurred [18].

2.2.3 Profitability Assessment

The benefit: cost ratio (BCR) was used to evaluate the economic viability of the different vegetable production technologies. The formula is explained below:

$$\text{BCR} = \frac{\sum B}{\sum C} \quad (1)$$

where, *B* represents net income earned from the sale of produce; *C* represents total cost incurred in the production process; ∑ refers to summation.

3. Results

3.1 Costs and Returns from Nakati, Bugga and Jobyo for Leafy versus Seed Production When Planted in Rows versus Traditional System

Labour services in different districts and farmer groups were offered at varying wage rates and mainly depended on the bargaining ability of the farmer since there were no standard rates. Vegetable cultivation for seed had higher cost compared to leafy, mainly due to harvest and post-harvest activities which are labour demanding especially seed processing.

3.1.1 Nakati

The total variable production costs were US$1,656 for leafy and US$2,450 for seed, in pure stand. In mixed cropping the costs were US$778 for leafy and US$1,225 for seed (Table 1). Nakati leafy yield was 59,032 kg/ha in pure stand compared to 25,492 kg/ha in mixed cropping. Seed yield was 1,225 kg/ha compared to 332 kg/ha under pure stand versus mixed cropping. Nakati was highly profitable when grown for leafy production compared to seed production both in pure stand and mixed. Net returns were US$15,211 compared to US$9,800, giving BCR of 9.2 and 4.0 for leafy and seed in pure stand, respectively. In mixed cropping, net returns were US$6,506 compared to US$2,100, giving BCR of 8.4 and 1.7 for leafy and seed, respectively.

3.1.2 Bugga

The total variable costs were US$1,380 for leafy and US$2,428 for seed, in pure stand. In mixed cropping costs were US$533 for leafy and US$672 for seed (Table 2). Bugga leafy yield was 11,972 kg/ha in pure stand compared to 9,278 kg/ha in mixed cropping. Seed yield was 4,038 kg/ha in pure stand compared to 110 kg/ha in mixed cropping. Bugga was more profitable when grown for seed compared to leafy production in pure stand. Net returns were US$43,721 compared to US$3,751, giving BCR of 18.0 and 2.7 for seed and leafy in pure stand, respectively. In mixed cropping however, net returns were US$3,443 compared to US$585, giving BCR of 6.5 and 0.9 for leafy and seed, respectively.

3.1.3 Jobyo

The total variable costs were US$1,308 for leafy and US$2,734 for seed, in pure stand. In mixed cropping costs were US$505 for leafy and US$1,206 for seed (Table 3). Jobyo leafy yield was 15,680 kg/ha in pure stand compared to 5,518 kg/ha in mixed cropping. Seed yield was 4,338 kg/ha in pure stand compared to 1,354 kg/ha in mixed cropping. Jobyo was more profitable when grown for seed compared to leafy production in pure stand. Net returns were US$40,647 compared to US$3,172, giving BCR of 14.9 and 2.4 for seed and leafy in pure stand, respectively. In mixed cropping, net returns were US$1,072 compared to US$12,334 giving BCR of 2.1 and 10.2 for leafy and seed, respectively.

3.2 Economic Evaluation of Mono versus Mixed Agronomic Practices of Growing IVs (Nakati, Jobyo and Bugga)

Results indicated that growing three vegetables

Table 1 Costs and benefits of Nakati production under pure versus mixed cultivation practices.

Category	Pure stand planted in lines, for leafy	Pure stand planted in lines, for seed	Mixed and broadcast, for leafy	Mixed and broadcast, for seed
1. Assets depreciation costs		Amount in US$		
Land rent, 1 ha	34.29	34.29	11.43	11.43
Spray pump (20 L) depreciation	15.43	15.43	5.14	5.14
Watering cans, five pieces (depreciation)	1.07	1.07	0.36	0.36
Hoes, six pieces (depreciation)	3.43	3.43	1.14	1.14
Weighing scales, one piece (depreciation)	8.00	8.00	2.67	2.67
2. Land preparation				
(i) Land clearing	68.57	34.29	11.43	11.43
(ii) 1st & 2nd ploughing	142.86	142.86	47.62	47.62
(iii) Harrowing/ridging	34.29	34.29	11.43	11.43
3. Inputs				
(i) Herbicides	17.14	17.14	8.57	11.43
(ii) Seed	250.00	250.00	125.00	125.00
(iii) Manure (chicken manure)	428.57	428.57	142.86	142.86
(iv) Pesticides (Cypermethrin, 5%)	-	188.21	-	141.16
(v) Egg yolk	206.35	-	154.76	-
4. Labour				
Planting	68.57	68.57	11.43	11.43
Weeding (three times)	102.86	137.14	77.14	102.86
Spraying	68.57	102.86	51.43	77.14
Harvesting	68.57	89.29	51.43	66.96
Processing	68.57	535.71	29.61	357.14
Packaging	-	350.00	-	95.00
Marketing	68.57	8.57	34.29	2.57
Total production costs (US$/ha)	1,655.71	2,449.71	777.73	1,224.76
Average yield per year (kg/ha)	59,032.00	1,225.00	25,492.00	332.50
Farm gate price (US$/kg)	0.29	10.00	0.29	10.00
Gross income (US$/ha)	16,866.29	12,250.00	7,283.43	3,325.00
Net return (US$/ha)	15,210.58	9,800.29	6,505.70	2,100.24
Benefit: cost ratio (BCR)	9.2	4.0	8.4	1.7

Cost calculations were based on exchange rate of Uganda Shs. 3,500 for US$1.

Table 2 Costs and benefits of Bugga production under pure versus mixed cultivation practices.

Category	Pure stand planted in lines, for leafy	Pure stand planted in lines, for seed	Mixed and broadcast, for leafy	Mixed and broadcast, for seed
1. Assets depreciation costs		Costs in US$		
Land rent, 1 ha	34.29	34.29	11.43	11.43
Spray pump (20 L) depreciation	15.43	15.43	5.14	5.14
Watering cans, five pieces (depreciation)	1.07	1.07	0.36	0.36
Hoes, six pieces (depreciation)	3.43	3.43	1.14	1.14
Weighing scales, one piece (depreciation)	8.00	8.00	2.67	2.67
2. Land preparation				
(i) Land clearing	68.57	34.29	11.43	11.43
(ii) 1st & 2nd ploughing	142.86	142.86	47.62	47.62
(iii) Harrowing/ridging	34.29	34.29	11.43	11.43

(Table 2 to be continued)

Category	Pure stand planted in lines, for leafy	Pure stand planted in lines, for seed	Mixed and broadcast, for leafy	Mixed and broadcast, for seed
3. Inputs				
(i) Herbicides	17.14	17.14	8.57	11.43
(ii) Seed	285.71	285.71	71.43	71.43
(iii) Manure (chicken manure)	428.57	428.57	142.86	142.86
(iv) Pesticides (Cypermethrin, 5%)	-	141.10	-	105.83
(v) Egg yolk	77.38	-	58.04	-
4. Labor				
Planting	68.57	68.57	11.43	11.43
Weeding (three times)	68.57	102.86	51.43	77.14
Spraying	34.29	68.57	25.71	51.43
Harvesting	34.29	35.71	25.71	26.79
Processing	11.43	71.43	11.43	47.62
Packaging	-	922.97	-	31.43
Marketing	45.71	11.43	35.43	3.43
Total production costs (Ug. Shs)	1,379.60	2,427.72	533.25	672.02
Average yield per year (kg/ha)	11,972	4,038	9,278	110
Farm gate price (US$/kg)	0.43	11.43	0.43	11.43
Gross income (US$/ha)	5,130.86	46,148.57	3,976.29	1,257.14
Net return (US$/ha)	3,751.26	43,720.85	3,443.04	585.12
BCR	2.7	18.0	6.5	0.9

Cost calculations were based on exchange rate of Uganda Shs. 3,500 for US$1.

Table 3 Costs and benefits of Jobyo production under pure versus mixed cultivation practices.

Category	Pure stand planted in lines, for leafy	Pure stand planted in lines, for seed	Mixed and broadcast, for leafy	Mixed and broadcast, for seed
1. Assets depreciation costs		Costs in US$		
Land rent, 1 ha	34.29	34.29	11.43	11.43
Spray pump (20 L) depreciation	15.43	15.43	5.14	5.14
Watering cans, five pieces (depreciation)	1.07	1.07	0.36	0.36
Hoes, six pieces (depreciation)	3.43	3.43	1.14	1.14
Weighing scales, one piece (depreciation)	8.00	8.00	2.67	2.67
2. Land preparation				
(i) Land clearing	68.57	68.57	11.43	11.43
(ii) 1st & 2nd ploughing	142.86	142.86	47.62	47.62
(iii) Harrowing/ridging	34.29	34.29	11.43	11.43
3. Inputs				
(i) Herbicides	17.14	17.14	8.57	11.43
(ii) Seed	214.29	214.29	62.50	62.50
(iii) Manure (chicken manure)	428.57	428.57	142.86	142.86
(iv) Pesticides (Cypermethrin, 5%)	-	94.00	-	70.50
(v) Egg yolk	77.38	-	58.04	-
4. Labor				
Planting	68.57	68.57	11.43	11.43
Weeding (three times)	68.57	102.86	51.43	77.14
Spraying	34.29	68.57	25.71	51.43
Harvesting	34.29	71.43	25.71	53.57
Processing	11.43	357.14	11.43	238.10

(Table 3 to be continued)

Category	Pure stand planted in lines, for leafy	Pure stand planted in lines, for seed	Mixed and broadcast, for leafy	Mixed and broadcast, for seed
Packaging	-	991.54	-	386.86
Marketing	45.71	11.43	16.00	8.57
Total production costs (Ug. Shs)	1,308.17	2,733.47	504.89	1,205.60
Average yield per year (kg/ha)	15,680	4,338	5,518	1,354
Farm gate price (US$/kg)	0.29	10.00	0.29	10.00
Gross income (US$/ha)	4,480.00	43,380.00	1,576.57	13,540.00
Net return (US$/ha)	3,171.83	40,646.53	1,071.68	12,334.40
BCR	2.4	14.9	2.1	10.2

Cost calculations were based on exchange rate of Uganda Shs. 3,500 for US$1.

purposely for seed, famers stand to gain more economic returns when planted as pure stand and in lines as shown by BCR 4.0, 18.0 and 14.9, for Nakati, Bugga and Jobyo, respectively. On the contrary, mixed cropping generated low economic gains giving BCR values of 1.7, 0.9 and 10.2 for Nakati, Bugga and Jobyo, respectively. This implies that a famer will maximise economic benefits in one vegetable and only minimal benefits from the other two vegetables.

Considering leafy vegetable production, results showed that Nakati and Jobyo did well in pure stand than mixed as indicated by BCR of 9.2 compared to 8.4 for Nakati and 2.4 compared to 2.1 for Jobyo. On contrary, Bugga when grown for leafy had considerably high economic returns in mixed system as indicated by BCR of 6.5 and 2.7 for mixed and pure stand, respectively.

4. Discussion

The economic analysis of IVs farming provides a rational basis for making decisions in allocating scarce resources among various options to maximize returns from the investments. The objective was to determine the economic performance of the traditional method (mix various IV seeds and broadcast them on the same plot of land) versus planting one vegetable on a given piece of land, and in rows. The study did not include fixed costs because the goal was to determine the costs incurred for each particular production practice, which were calculated using the current input prices and labour costs [18]. Only variable costs of vegetable production were considered, which were organized into Assets/Farm tools depreciation costs, inputs and labour costs. Variable costs included labour and all the input costs directly related to the production practices, i.e., hiring land, fertilizers cost, seeds, land preparation, planting, weeding, and pest and disease control. Harvest costs included labour cost of fruit picking, seed processing and packaging.

Basing on partial budget concept, the total variable production costs for this experiment considered land and farm tools rental/opportunity field cost, i.e., hiring land hectare per year, depreciation of farm tools (spray pump (20 L), watering cans (5), hoes (6), and weighing scale (1)). Cost of transporting inputs to, and outputs from trial sites were not included in the gross margin because output was sold at farm gates hence no extra cost of transportation. Differences in labour prices, quantity of inputs used, price for inputs, purpose for growing vegetables (either for seed or leafy production) among other factors, caused variations in production costs from one farmer group to another. It is also interesting to note that at times mixed cropping had attractive BCR and yet it had low yields, hence low gross income. This is because in mixed practice the labour cost is shared among three crops, hence reducing its proportionate burden on the revenue realised from each crop.

Most farmers sell leafy vegetables to vendors at farm gate prices. They buy a heap of about 25 kg at US$2.86 for Nakati, Bugga and Jobyo. If a famer takes leafy vegetable to nearby trading centres (e.g.,

Nakaseke and Wakiso towns) he sells about 25 kg heaps at US$4.29. Traders with stalls in market who sell in retail charge a bundle of 300-500 g at US$0.14. For vegetable seeds, farmers in groups sell Nakati, Bugga and Jobyo seeds to a seed company (Simlaw Seed Co.) at US$10.0, 11.4 and 10.0 per kg, respectively. In open market, however, 20 g was sold at US$0.75.

With a BCR of 9.2 and 4.0 for Nakati sold as leafy compared to seed production, respectively, results of this study show that Nakati was 2.3 times more profitable when sold as leafy compared to when sold as seed. For Bugga and Jobyo on the other hand, the net income earned from the sale of seed from 1 ha was 6.7 times and 6.2 times higher, respectively, than that earned from leafy pure stand planted in lines. If a famer can irrigate, he/she may get three harvest cycles a year for seed and four cycles for leafy, thus boosting the benefits even more.

Generally, results on economics of vegetable commercial farming indicate that famers stand to gain higher net returns when they plant vegetables as pure stand and in lines. Bugga was an exception since it did well in both mixed and pure stand when planted for leafy, giving yields of 11,972 kg/ha in pure and 9,278 kg/ha in mixed cropping. This is because Bugga establishes faster and suppresses Jobyo and Nakati. Thus, as observed above, in mixed cropping farmers stand to gain in one crop. Notsi [16] observed that mixed cropping indigenous farming systems may have a risk of low production due to high plants completion of water and space. Results of this study show that although farmers may get a variety of crops from the same piece of land in the mixed cropping system over a prolonged period, the economic benefits are not very attractive as compared to pure stand.

5. Conclusions

Results from this study indicate that IV production in Wakiso, Nakaseke and Mukono districts is a profitable enterprise as implied by BCR > 1. Growing indigenous leafy vegetables in pure stand either for seed or leafy production proved to be more profitable than mixed system with BCR of 18.0, 14.9 and 4.0 for seed production and 2.7, 2.4 and 9.2 for leafy production of Bugga, Jobyo and Nakati, respectively. In mixed cropping system, however, BCR were 0.9, 10.2 and 1.7 for seed and 6.5, 2.1 and 8.4 for leafy production of Bugga, Jobyo and Nakati, respectively. Thus, although farmers may get a variety of crops from the same piece of land in the mixed cropping system over a prolonged period, it is more profitable to grow the vegetables separately in pure stand. Considering that most farmers in Uganda grow IVs on a small scale, a farmer is better off sub-dividing the land into smaller portions then growing each vegetable species on separate patches and in lines, rather than mixing seeds then broadcasting them.

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