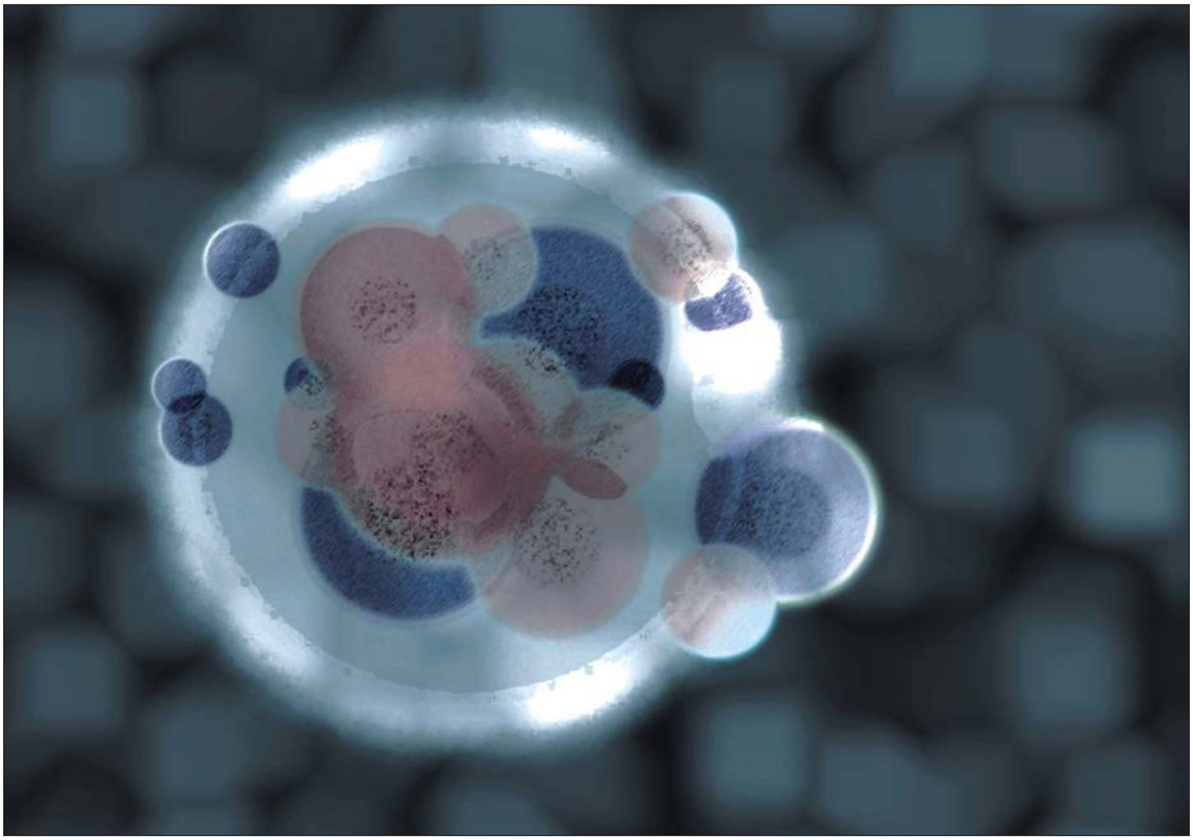

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Yield and Quality of Potato (*Solanum tuberosum* L.) Seed Tuber as Influenced by Inter and Intra Row Spacing at Bako, Western Ethiopia

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Abstract: An experiment was conducted at Bako Agricultural Research Centre in the production season of 2011/12 with the purpose of identifying the best combination of inter and intra row spacings for the optimum production of potato (*Solanum tuberosum* L.) seed tuber with marketable size and good flour quality. Six levels of inter (60, 65, 70, 75, 80 and 85 cm) and three levels of intra row spacings (20, 30 and 40 cm) were used in 6×3 factorial combination arranged in a randomized complete block design with three replications. Most of the observed variables were significantly affected due to the variation in the treatment combination between inter and intra row spacings. Narrow spacings shifted seed tuber distribution from larger to the smaller and undesirable tubers considered from marketable point of view. Though, total yield increased under narrower spacing conditions, marketable tubers are more promising for encouraging farmers to continually produce seed tubers. These therefore require relatively wider spacing to have more number of marketable size tubers. To achieve this, the study identified 70-75 cm inter and 20-30 cm intra row spacing as the best spacing combination for optimum yield and good quality potato seed tuber.

Key words: Potato seed, specific gravity, tube number, tuber flour, spacing

INTRODUCTION

Potato (*Solanum tuberosum* L.) for many years since its introduction (in 1958) was limited to homestead as a garden crop. But, gradually the crop became a very important crop in many parts of Ethiopia and its production increased from year to year (Gebremedhin *et al*., 2008). Currently, it is one of the major food crops grown in the high and mid altitudes in western part of the country serving as food and sources of income for farmers specially during food shortage and when grains depleted from stores (Girma *et al*., 2004). Potato indeed could become an important food crop, as it can be planted in dry areas not suitable for other crops and a potential crop for producers. The crop is mainly produced on fertile soils but also grown on sandy soils both under irrigation and rain fed conditions (Sadowska *et al*., 2004). It is a high biological value crop that gives an exceptionally high yield with more nutritious content per unit area per unit time than any other major crops (Miheretu, 2014).

The total area under potato production or cultivation in Ethiopia was about 51000 ha with an average productivity of 8 t ha^{-1}. Currently the total area under production reaches 69784 ha and the production estimated to be 5,723,325 quintals. The productivity of the crop in the country is low as compared to the world average of 17 t ha^{-1} and 11 t in Africa (Hirpa *et al*., 2010).

Many factors are identified as the potential causes for the low yield in Ethiopia, but the lack of high quality seed seems to explain most of the differences with the potential yields of the existing potato varieties. Increasing the availability of high quality seed would be a priority in order to significantly increases potato yields in the region. In addition to the availability, quality of the available potato seed is a key factor in profitable potato production and farmers became aware of how seed potato quality affects yield. This therefore requires a systematic investigation of the problems that result to a permanent supply of high quality seeds in order to increase their production and productivity on the limited land resource that the farmers have.

The quality of seed tubers produced for production purpose depend on seed tuber size and plant population density per unit of land. But, researchers indicated that plant population per unit of land varies depend on the intended use of the crop for tuber seed or ware (Berga *et al*., 1994). In addition, depending on seed tuber size and the amount of seed tuber required different

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spacings between plants and also between rows were suggested for producing good quality seed tubers. However, farmers in western parts of Ethiopia are not using the recommendations either due to lack of awareness or it may not fit to the conditions of that specific area. Hence, it is important to identify appropriate plant population per unit land area for that study region. This research was therefore conducted to identify the best combination of inter and intra row spacing for optimum production of seed tuber with marketable size and good quality flour.

MATERIALS AND METHODS

Description of the study area: The study was conducted at Bako Agricultural Research Center (BARC) during 2011/12 main cropping season. The center located in the western parts of Ethiopia at a distance of 260 km away from Addis Ababa at a latitude of 9°6'N, longitude 37°9'E and altitude of 1650 m above sea level. The area has a humid climate with annual mean minimum and maximum temperature of 13.5 and 26.9°C, respectively. It receives average annual rainfall of 1424 mm extending from May to November with the maximum precipitation in the months of June to August (OARI, 2002). The soil of the area is characteristically reddish brown Nitosols, with a pH of 4.8-5.0.

Experimental design and treatments: The experiment consisted of six levels of inter row spacing (60, 65, 70, 75, 80 and 85 cm) and three levels of intra row spacing (20, 30 and 40 cm) and was set up in a 6×3 factorial design arranged in RCBD with three replications. Potato varieties called 'Jalene' was used in this experiment as it is growing widely in the area and has got acceptance by farmers due to its high yielding and resistance to disease and pest as well as acceptability by consumers.

Data collection and analysis: Data on yield, yield components and quality variables were collected and subjected to analysis of variance (ANOVA) using SAS computer software version 9.2 (SAS, 2008). When ANOVA showed significant differences, mean separation was carried out using LSD (least significant difference) test at 5% level of significance.

RESULTS AND DISCUSSION

Yield and yield components: The analysis of variance showed that the interaction effect of inter and intra row spacing resulted to statistically significant ($p<0.05$) differences with respect to average tuber yield per plant (g pL^{-1}), total tuber number per ha and marketable tuber yield per ha (Table 1) and highly significant differences with respect to total tuber yield (t ha^{-1}), average tuber number per plant and marketable tuber number per ha (Table 2).

Maximum yield per plant, 933 g was obtained from inter row spacing of 85 cm combined with intra row spacing of 40 cm (Table 1). This revels that using wider spacing probably decreases the yield ha but resulted to increased yield per plant. The lowest amount of yield (408 g) on the other hand was recorded from treatment combination of 75×20 cm resulting to 56% yield difference per plant.

Table 1: Interaction effect of inter and intra row spacing on average tuber weight (g pL^{-1}), total tuber number and marketable tuber yield (t ha^{-1})

Treatments (cm)	Average tuber yield (g pL^{-1})	Total tuber No. ha^{-1}	Marketable tuber yield (t ha^{-1})
60×20	683.3^{c-f}	54880^{a}	24.94^{bcd}
60×30	652.0^{def}	48700^{abc}	22.28^{fgh}
60×40	425.7^{i}	45570^{a-d}	21.66^{gh}
65×20	796.7^{bc}	49630^{abc}	37.02^{a}
65×30	617.0^{fg}	38230^{a-e}	29.56^{cde}
65×40	776.7^{bcd}	41700^{a-e}	25.33^{efg}
70×20	410.0^{i}	27700^{cde}	22.47^{fgh}
70×30	443.7^{hi}	26033de	22.19^{fgh}
70×40	567.0^{fgh}	29370^{b-e}	22.71^{fgh}
75×20	408.3^{i}	38520^{a-e}	23.62^{fgh}
75×30	471.0^{hi}	36600^{a-e}	25.58^{d-g}
75×40	506.7^{ghi}	22940^{e}	28.69^{de}
80×20	758.7^{b-e}	45830^{a-d}	33.33^{abc}
80×30	637.7^{ef}	45830^{a-d}	29.46^{cde}
80×40	842.0^{ab}	50450^{ab}	34.16^{ab}
85×20	686.0^{c-f}	47580^{a-d}	26.51^{def}
85×30	651.0^{def}	36530^{a-e}	26.16^{d-g}
85×40	933.0^{a}	38590^{a-e}	20.17^{h}
CV (%)	12.43	10.29	10.24

Means followed by the same letter(s) within the same column are not significantly different at a probability level of 0.05

Table 2: Interaction effect of inter and intra row spacing on total tuber yield (t ha^{-1}), average tuber No. $plant^{-1}$ and marketable tuber No. ha^{-1}

Treatments (cm)	Total tuber yield (t ha^{-1})	Average tuber No. $plant^{-1}$	Marketable tuber No. $plant^{-1}$
60×20	31.62^{bcd}	15.00^{b}	33770^{a-d}
60×30	23.39^{fg}	14.66^{b}	33770^{a-d}
60×40	22.60^{fg}	12.00^{b-e}	31670^{a-d}
65×20	38.39^{a}	18.66^{a}	38400^{a}
65×30	30.23^{cde}	11.33^{cde}	26500^{a-d}
65×40	26.62^{ef}	14.00^{bc}	31320^{a-d}
70×20	23.34^{fg}	6.66^{h}	16350^{d}
70×30	22.92^{fg}	7.33^{gh}	18350^{cd}
70×40	23.26^{fg}	9.66^{efgh}	18590^{bcd}
75×20	24.56^{fg}	7.33^{gh}	25700^{a-d}
75×30	26.55^{ef}	8.00^{fgh}	23630^{a-d}
75×40	29.76^{cde}	7.33^{gh}	31190^{a-d}
80×20	34.22^{abc}	12.33^{b-e}	36670^{ab}
80×30	30.15^{cde}	11.00^{c-f}	35900^{abc}
80×40	35.10^{ab}	12.66^{b-e}	37200^{a}
85×20	27.31^{def}	13.00^{bcd}	35340^{abc}
85×30	27.03^{def}	10.33^{d-g}	26380^{a-d}
85×40	20.81^{g}	12.00^{b-e}	30670^{a-d}
CV (%)	10.58	16.52	11.67

Means followed by the same letter(s) within the same column are not significantly different at a probability level of 0.05

In contrary to the amount of yield obtained, tuber number ha increased as the spacing between plants and rows decreased. Greatest number of tubers ha (54880) was obtained from the treatment combination of 60×20 cm while the lowest tuber number (22940) was recorded from treatment combination of 70×40 cm (Table 1). The difference in this case was about 58% indicating the potentiality of compensating the amount of yield differences observed above. Because, the increased yield was mainly attributed to more number of tubers produced at the higher plant population ha.

In the narrower treatment combination, 65×20 cm highest marketable tuber yield (37.02 t ha^{-1}) were observed than in the wider spacing combinations. As the number of tubers per ha increases there is a chance of obtaining greater amount of tuber yields that can be marketed than in the reduced number of tubers ha.

The analysis of variance in this experiment indicated that total tuber yield (t ha^{-1}), average tuber number per plant and marketable tuber number ha (000's per ha) were found to be highly significantly affected ($p<0.01$) by the interaction effects of inter and intra row spacings (Table 2).

The highest total tuber yield (38.19 t ha^{-1}) was obtained from treatment combination of 65×20 cm while the lowest (21.22 t ha^{-1}) yield was recorded from the treatment combination of 85 cm inter and 40 cm intra row spacing. The increased yield was attributed to more tubers produced at higher plant population ha than in the wider spacing (Love and Asunta, 1999). Similarly, as the spacing between plants and rows decreases tubers number per plant was found increasing. In a treatment combination of 65×20 cm around 18.66 tubers per plant were recorded resulting to 38,400 marketable tuber numbers ha. As the inter row spacing increased from 65-70 cm for the same intra row spacing (20 cm), the number of tubers per plant and the corresponding number of marketable tubers ha decreased by 64 and 57% resulting to 6.66 tubers per plant and 16,350 marketable tubers ha, respectively.

The analysis of variance showed that the interaction effects of inter and intra row spacing revealed highly significant ($p<0.01$) differences with respect to potato tuber size (Table 3). Increasing the spacing between plants and rows from 60×30 cm to 85×40 resulted to a 53% decreased in number of under sized (<20 mm) potato tubers from 81.66 to 38.66. Similarly, number of small sized tuber (20-30 mm) was also decreased from 86 to 26 as the spacing increased from 60×30 cm to 75×30 cm. When the number of medium sized tubers (30-40 mm) were considered, relatively higher number (88.33) was found at the narrower spacing of 65×20 cm and the lower number

Table 3: Interaction effect of inter and intra row spacing on under sized, small sized and medium sized tuber number/plot

Treatments (cm)	Under sized tuber No. $plot^{-1}$	Small sized tuber No. $plot^{-1}$	Medium sized tuber No. $plot^{-1}$
60×20	62.33^{bc}	86.33^{a}	81.00^{ab}
60×30	78.33^{a}	75.66^{a}	61.33^{def}
60×40	51.33^{c-f}	59.66^{b}	65.00^{c-f}
65×20	81.66^{a}	85.66^{a}	88.33^{a}
65×30	56.33^{b-e}	59.00^{bc}	54.00^{fgh}
65×40	56.33^{b-e}	56.33^{bcd}	58.66^{ef}
70×20	60.00^{bcd}	32.33^{gh}	43.33^{hij}
70×30	58.33^{b-e}	36.33^{fgh}	36.00^{j}
70×40	44.00^{fg}	36.33^{fgh}	41.33^{hij}
75×20	43.00^{fg}	37.33^{e-h}	44.00^{g-j}
75×30	38.66^{g}	26.00^{h}	39.33^{ij}
75×40	63.66^{b}	37.00^{fgh}	55.00^{fgh}
80×20	41.00^{fg}	47.00^{b-f}	73.33^{bcd}
80×30	52.00^{b-f}	51.33^{b-e}	73.00^{b-e}
80×40	48.66^{d-g}	46.66^{c-f}	76.00^{abc}
85×20	47.33^{efg}	45.33^{c-g}	81.00^{ab}
85×30	51.33^{c-f}	44.66^{d-g}	51.33^{f-i}
85×40	38.66^{g}	33.33^{fgh}	58.33^{fg}
CV (%)	13.69	17.03	14.43

Means followed by the same or no letter(s) within the same column are not significantly different at a probability level of 0.05

(36) was obtained at a spacing combination of 70×30 cm. Undersized and small sized tubers are less desired because of the low market prices (Hossain *et al*., 2011). But, closer spacing increased the number of these undesired potato tubers result to economic loss for the farmers. Medium sized tubers are the most desired ones for their seed value and higher market prices. But, potato seed tubers growing at a narrower spacing compete for the available resources as the result some of the tubers are of large size and some are of smaller size resulting to uneven size distribution among the tubers. To get the economically important tuber sizes, relatively wider spacings are required to reduce the competitions occurring between tubers so that they develop more uniform seed tubers upon maturation.

The interaction effects of inter and intra row spacing was also observed between treatments with respect to the weight per plot of each of potato tubers categorized as under sized and small potato tubers but not on the medium sized potato tubers (Table 4).

Maximum under sized tuber weight per plot (530 g) was registered at treatment combination of 60×20 cm than in a treatment combination of 80×20 cm. Similarly, small sized potato tubers of narrow inter and intra row spacings also gave greater weight than those small sized potato seed tubers found in the wider spacings. This was probably due to the largest number of under and small sized seed tubers recorded from the narrower treatment combinations. Berga *et al.* (1994) from their previous result concluded that stem number per plant and tuber number per plant are positively correlated. As tuber number per plot increase, weight of these tubers per plot also increases. But, it was observed that average weight per tuber increases with increasing inter and intra row spacing.

Medium sized tubers and tuber specific gravity (g cc^{-1}) were not affected by the interaction effects of inter and intra row spacings (Table 5). Intra row effect as a main factor did not also result to differences with respect to these variables but seems to have more responsive effect than inter row spacing. However, inter row spacing results to the difference in medium sized potato tubers and their specific gravity only at wider spacings.

Table 4: Interaction effect of inter and intra row spacing on under sized tuber weight (g $plot^{-1}$) and Small sized potato tubers (g $plot^{-1}$)

Treatments (cm)	Ustw (g $plot^{-1}$)	Sstw (g $plot^{-1}$)
60×20	530^{a}	1627.0^{a}
60×30	530^{a}	626.0^{efg}
60×40	363.3^{b-e}	723.3^{efg}
65×20	393.3^{bc}	1800.0^{a}
65×30	333.3^{b-e}	1143.0^{cd}
65×40	440.00^{ab}	1107.0^{cd}
70×20	323.3^{b-e}	630.0^{efg}
70×30	370.00^{bcd}	1507.0^{ab}
70×40	316.7^{b-e}	940.0^{de}
75×20	233.3^{ef}	293.3^{h}
75×30	337.3^{b-e}	483.3^{fgh}
75×40	416.7^{abc}	753.3^{ef}
80×20	177.00^{f}	937.0^{de}
80×30	241.3^{def}	1280.0^{bc}
80×40	363.3^{b-e}	1700.0^{a}
85×20	303.3^{c-f}	423.3^{gh}
85×30	390.00^{bc}	653.3^{efg}
85×40	248.3d^{ef}	636.7^{efg}
CV (%)	23.4	20.13

Means followed by the same letter(s) within the same column are not significantly different at 0.5 significance/probability level

Table 5: Effect of inter and intra row spacing on medium size tuber weight (g $plot^{-1}$) and potato tuber specific gravity (g cc^{-1})

Treatments	Mstw (g $plot^{-1}$)	Specific gravity (g cc^{-1})
Inter row (cm)		
60	4.98^{b}	1.08^{b}
65	4.90^{b}	1.08^{b}
70	4.32^{b}	1.07^{b}
75	4.28^{b}	1.10^{b}
80	7.00^{a}	1.25^{a}
85	6.50^{a}	1.09^{b}
CV (%)	24.32	13.83
Intra row (cm)		
20	5.36^{a}	1.15^{a}
30	5.34^{a}	1.10^{a}
40	5.28^{a}	1.08^{a}
CV (%)	24.32	13.83

Means followed by the same letter(s) with in the same column are not significantly different at 0.05 probability level

Potato tuber flour yield: Analysis of variance showed very highly significant ($p<0.0001$) differences for the interaction effect of inter and intra row spacing on potato tuber flour yield (Table 6). Significantly maximum tuber flour yield (4.70 kg) was obtained at the combination of inter row spacing (85 cm) and intra row spacing of (40 cm).

In contrary to this, lower tuber flour (0.78 kg) was recorded from treatment combination of 70×20 cm. This finding indicates that larger size and reasonable weight can be obtained from wider spacing that resulted to relatively better flour yield than small sized potato tubers.

Correlation analysis among yield and quality parameters: The correlation coefficient among response variable (Table 7) revealed that, the potato tuber yield and yield

Table 6: Interaction effect of inter and intra row spacing on tuber flour yield (kg $plot^{-1}$)

Treatments	Tf (kg $plot^{-1}$)
60×20	1.33^{fgh}
60×30	1.23^{f-i}
60×40	1.30^{f-i}
65×20	1.40^{fgh}
65×30	0.98^{hi}
65×40	1.73^{def}
70×20	0.78^{i}
70×30	1.63^{d-g}
70×40	1.23^{f-i}
75×20	1.16^{ghi}
75×30	1.18^{ghi}
75×40	1.53^{efg}
80×20	2.13^{d}
80×30	2.71^{c}
80×40	4.00^{b}
85×20	2.73^{c}
85×30	2.05^{de}
85×40	4.7^{a}
CV (%)	17.05

Means followed by the same letter(s) within the same column are not significantly different at 0.5 significance/probability level

Table 7: Simple pearson correlation on potato yield and quality parameters

	Mty	Tty	Mtnh	Ttnh	Tnp	Twp	Tf	Ustn	Sstn	Mstn	Lstn
Mty	1	0.98***	0.09^{ns}	0.14^{ns}	0.46**	0.37**	0.08^{ns}	0.23^{ns}	0.4**	0.58***	0.31*
Tty		1	0.32*	0.50*	0.46**	0.37**	0.08^{ns}	0.25^{ns}	0.41**	0.59***	0.3*
Mtnh			1	0.95**	0.67**	0.58***	0.36*	0.15^{ns}	0.64***	0.09***	0.69***
Ttnh				1	0.65**	0.46**	0.22^{ns}	0.21^{ns}	0.68***	0.86***	0.57**
Tnp					1	0.62***	0.05^{ns}	0.3*	0.57***	0.66***	0.49**
Twp						1	0.07^{ns}	-3.5^{ns}	-0.09^{ns}	0.31*	0.53**
Tf							1	-0.14^{ns}	-0.11^{ns}	0.17^{ns}	0.24^{ns}
Ustn								1	0.59***	0.24^{ns}	-15^{ns}
Sstn									1	0.64*	0.25^{ns}
Mstn										1	0.57**
Lstn											1

*Significant, **highly significant, ***very highly significant at 0.05, 0.01 and <0.001 level of significance. Mty: Marketable tuber yield (t ha^{-1}), Tty: Total tuber yield (t ha^{-1}), Mtnh: Marketable tuber number per hectare, Ttnh: Total tuber number per hectare, Tnp: Total plant number, Twp: Total plant weight (g), Tf: Tuber flour (kg), Ustn: Under size tuber number, Sstn: Small size tuber number, Mstn: Medium size tuber number, Lastn: Large size tuber number components were significantly and positively correlated with each other. Total tuber yield was positively and significantly correlated with tuber number (r = 0.46**) and tuber weight (r = 0.37**). Total marketable tuber number ha on the other hand, was positively and strongly associated with tuber number (r = 0.67**), tuber weight (r = 0.58*) and size, while total tuber number ha was positively and significantly correlated with total tuber number per plant (r = 0.65*).

CONCLUSION

Average tuber yield per plant increases as the spacing between plants and rows increases. However, this results to the decreased total tuber number as well as marketable yield expressed ha base. The narrower spaces shifted the seed tuber size distribution from large size to the undersized and small sized seed tubers which are undesirable if the intended use of the crop is for tuber seed production. Since, most of the yield and quality variables were observed to have positive and strong association with each other, a spacing adjustment made for one of the variable improves the value of the other associated variables and hence yield and quality. From the economic point of view, rather than the total yield obtained ha, marketable tuber yield ha seems promising and encouraging farmers to continually produce and make potato seed tubers available for continuous production. This research activity therefore identified 70-75 cm inter row and 20-30 cm intra row spacings as the best combination of spacing for optimum production of seed tuber with marketable size and good quality flour.

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