# THE EFFECTS OF SEED TUBER SIZE AND SPACING ON THE YIELD, DRY MATTER CONTENT AND DAUGHTER TUBER SIZE IN THREE POTATO *(SOLANUM TUBEROSUM L.)* VARIETIES

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## APPROVAL

The University of Zambia approves this dissertation of Nkandu Nicholas Mwansa as fulfilling the requirements for the award of the degree of Master of Science in Agronomy.

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# DECLARATION

I Nkandu Nicholas Mwansa hereby declare that this dissertation represents my own work and that it has not previously been submitted at this or any other university.

**Signed:** ..............................

**Date:** 10/09/02

## DEDICATION

This work is dedicated to my wife Stella and my son Nicholas (Jr.)

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## ABSTRACT

A field trial was conducted at Mt. Makulu Research Station in Chilanga, Zambia to determine the effect of seed tuber size and plant spacing on the yield, dry matter content and daughter tuber sizes of three potato varieties. The trial was also meant to determine the combination of seed tuber size and spacing that would give highest economic returns. The varieties used were Up To Date, Baraka and Pentland Dell while the four seed sizes included 26-30 mm, 31-35 mm, 36-40 mm and 41-45 mm at two interrow spacings of 75 cm and 90 cm.

Treatments were arranged in a split-split plot design with varieties as main plots, spacing as sub plots and seed tuber sizes as sub-sub-plots. The treatments were replicated three times.

Results showed that seed size had no significant influence on the total tuber yield or on daughter tuber sizes in all varieties. Spacing at 75 cm produced a higher tuber yield (27.51t/ha) than at 90 cm (24.89t/ha). The percentage of larger tubers however was higher at 90 cm spacing where 35% of tubers were larger than 50 mm compared to 27% at 75 cm. Spacing at 90 cm produced tubers of higher dry matter content (19.04%) than spacing at 75 cm (17.73%). The largest seed tuber size (41-45 mm) produced tubers of higher dry matter content (18.83%) than the smallest seed size (25-30 mm) which gave a dry matter content of 17.76% across varieties. The highest economic returns were obtained using seed size 26-30 mm at a spacing of 20 cm x 75 cm.

# 1.0 INTRODUCTION

## 1.1 Background and Justification

Potato (Solanum tuberosum L.) is normally multiplied by the use of seed tubers although the use of True Potato Seed (TPS) is becoming important in some areas. (Wiersema, 1989). The use of tubers as planting material means that large quantities of seed tubers are needed for planting which depending on size of tubers can be as high as 2-3 tons/ha (Namasiku 1995). At the same time, the multiplication rate of potato is very low; as low as 1:10 compared to most cereals which can have a rate of 1:100 or higher (Wiersema, 1980).

Current potato production technology is costly in most developing countries. Studies in many countries indicate that variable production costs for potatoes are generally more than 1000 US dollars per hectare (CIP, 1984) with the crop's single most costly input being the planting material. In tropical Africa and South America, seed tubers generally account for about 30% of the total variable cost of production while in Asia and Central America, they go up to about 50% of the total (CIP, 1984). Even where growers do not purchase seed but retain it from the previous harvest, seed still has a high cost since the potatoes used could have been eaten or sold had it not been necessary to plant them.

It has been a tradition of many farmers in developing countries to use left over small tubers for planting their potato crop (Wiersema et al, 1987). The comparative performance of such small tubers has not been extensively studied in many countries

(Wiersema et al, 1987). While it is established that the size of a seed potato may influence yield, the literature does not clearly indicate the optimum size of seed that can be planted under specific varieties and conditions to get the best economic returns (Kapoor, 1950; Ahmad and Quasen, 1968). It is however established that small tubers produce more sprouts per unit weight than larger tubers so that with smaller tubers of similar weight, a larger area can be planted. This has been the basis for setting different prices for different seed size ranges.

The yield of potato is also influenced by plant spacing. In general, a closer spacing, up to an extent, increases yield of potato tubers per unit area. (Taleb et al, 1973; Smith, 1977). In addition to influencing total yield, plant density affects the average tuber size and consequently the desired size of daughter tubers.

Both the size of seed tubers and plant density have an effect on the dry matter content of daughter tubers. Havecort, (1991) found out that potato plants grown from smaller tubers produce daughter tubers of lower dry matter content than those produced from larger tubers unless the season is long enough for those planted from smaller tubers to catch up and reach similar values. It is also established that plant density affects dry matter accumulation by shading (Burton, 1989).

It is important to note that potato yields in developing countries are on average less than half the levels obtained in North America or Europe. (Horton, 1987); One reason is that the economically optimal yield is lower in most developing countries than in the developed world. Furthermore, because of differences in environmental conditions, levels of development and prices, the scope for direct transfer of technology from developed to developing areas is limited, thus, it would be erroneous to conclude that gaps in yield among countries or regions could easily be filled by adopting technologies from the Americas or Europe without adapting them to local conditions.

In view of the above considerations, it becomes important to establish the performance of various seed sizes of potato varieties used in Zambia at different inter-row spacings in order to ascertain which combination would give the best economic returns under the conditions. Assuming that a substantial yield decrease results from the use of smaller seed size, the economic comparative advantage gained by the increased area that can be planted using smaller tubers can be measured against the higher yields obtained from the use of large tubers. The study of the size of daughter tubers as well as dry matter content as affected by variety, spacing and seed tuber size may help potato growers determine expected sizes and quality of daughter tubers so that adjustments can be made in accordance with expected use and consumer preferences.

## 1.2 Objectives

The study was designed to evaluate the following: -

(a) The effect of seed tuber size and spacing on the yield of three potato varieties used in Zambia.

(b) The effect of seed tuber size and spacing on daughter tuber sizes and dry matter content of the three potato varieties.

(c) The best combination of seed tuber size and spacing that would give the highest economic returns for the three varieties.

# 2.0 LITERATURE REVIEW

## 2.1 Importance of Potato

Potato is the second most widely distributed crop in the world after maize. It is grown in about 140 countries of which more than 100 are located in the tropical and subtropical zones (Beukema and Van der Zaag, 1990). In volume of production, potatoes rank fourth after wheat, maize and rice while in the developing world, potatoes have the highest rate of production growth (CIP, 1984). There is evidence abound indicating why the potato should be exploited for the tropics. Firstly, the crop is the best nutritively balanced among all major plant foods (Sawyer, 1980). The balance between proteins and calories is excellent while there are no limiting amino acid constituents such as exist in many cereal and legume crops. Potentially, more food value (calories and proteins) can be produced per units of time and water with the potato than with any other major plant food. Burton, (1989) observed that potato is a good source of energy, proteins, vitamins and minerals.

In many countries, potatoes from part of the basic diet while in others, it is consumed as a vegetable. Processed potatoes in form of French fries and crisps are very popular throughout the world while large amounts are also used for starch production especially in the Netherlands, Eastern Europe and Japan (Beukema and Van der Zaag, 1990). In Zambia potato production and consumption has risen markedly and is becoming of increasing importance (Namasiku, 1995), in many cases replacing the conventional maize meal as part of the main diet especially with the affluent in urban areas. The potential for expansion of both the areas under commercial production and yield levels is high.

## 2.2 Seed Tuber size and Sprout growth

Horton, (1987) reported that seed tuber size affects sprout growth in two ways. Firstly, large tubers produce more sprouts and therefore more main stems than small ones since sprout development is positively related with tuber surface. Secondly, sprouts grow faster on large tubers because they have greater food reserve available for each sprout than small tubers do. Bleasdale, (1984) reported that the number of eyes on a potato tuber is not directly proportional to its size. Larger potatoes have fewer eyes per unit width so that the amount of reserves per sprout is higher as seed size increases but not in direct proportion. In other words, doubling the size of seed planted does not necessarily mean doubling the amount of reserves available per sprout.

## 2.3 Seed size and Crop establishment

A seed tuber provides a source of nourishment for the young potato plant and this factor enables the young potato seedling to establish (Burton, 1989). Struick and Lommen, (1995) documented that the development of haulms of potato produced from smaller tubers is slow resulting in poor light interception during the early period of the growing season. If for one reason or another, the growing season becomes limited in length, this poor early growth will result in reduced yields. On the other hand, if the growing season is not limited in length, the yields may still decline because the period *during which light interception is maximum* will be shorter. They further indicated that the effect of seed size on crop establishment would largely depend on climate. In tropical climates, slow haulm development is less of a problem than in temperate climates owing to high temperatures in the former. In addition, when it comes to yields, the growing season in tropical climates may not be limited in length so that more time is available to catch up with a crop produced from larger tubers. This is in agreement with Wiersema (1989) who noted that small seed tubers may have a better chance in the field in warmer climates than in temperate regions because of the less limiting season in warm climates. On comparing performance of small and large seed tubers in temperate regions, Beukema and Van der Zaag (1990) observed that larger seed was only advantageous if the soil and weather conditions at planting were unfavourable or if the growing season was short. Zumbado (1987) carried out a similar field study in Costa Rica where results showed a tendency of a decreasing production with decreasing seed size. It was also observed that the small seed sizes produced larger daughter potatoes. The results of Benitez et al (1987) on potato variety Desiree in Cuba did not show any significant effect of seed size on yield in contrast with Burton (1989) who reported that there is a direct relationship between total yield and the size of seed tubers planted.

## 2.4 Seed size, Plant Density and Tuber Yield

Plant density in potato is determined by the number of main stems that come out of a seed tuber. Such a collection of plants is commonly known as "hill" (Burton, 1989). Each constituent plant in a "hill" will produce tubers and ideally, the greater the number of plants in a "hill" the greater will the number of tubers produced be. Because of competition however, the individual daughter tubers tend to be smaller. This trend is considerably affected by cultivar (Burton, 1989), a factor usually overlooked in blanket spacing recommendations for many varieties.

Beukema and Van der Zaag (1990), observed that plant density affects total tuber yield as well as the average tuber size. Increasing plant density increases yields but decreases average tuber size. The increased yields at higher plant density was attributed to the ground being covered with green leaves earlier; fewer lateral branches being formed and tuber growth starting earlier.

According to the AVRDC (1990), the ideal spacing and plant density are those that maximize marketable yield without unduly increasing costs. Since potato seed costs are high, it is important that growers use their seed as efficiently as possible when aiming for optimum population as Mould, (1989) observed. In order to achieve this, the interaction between seed size and spacing must be appreciated as these two components determine the amount of seed required per hectare for optimum population. The same author noted the fact that the increase in the number of eyes on a potato plant is not directly proportional to size so that a given total mass of small seeds at close spacing may produce a larger number of stems than an equal total mass of large seeds at a correspondingly wider spacing. It is also important to note that the aspect of marketable yield in potato is very cardinal. (Beukema and Van der Zaag, 1990). Bigger tubers may be desired for table potato whereas smaller tubers are preferred as seed potato. On the extreme end, very small potatoes may not even be marketable at all in some areas. In a field trial, Benitez et al (1987) found that yield of potato from seed size 30-35 mm planted at a wider spacing of 90 x 20 cm was not significantly different from that planted at a closer spacing of 90 x 15 cm. However, the wider spacing was found to be economically justifiable as it used less planting material. Furthermore, the yield from 35 - 45 mm seed size planted at a wider spacing was higher than that planted at a closer spacing. In this case, the use of wider spacing is even more justified. In Bangladesh, Siddique et al (1987) obtained highest economic returns from spacings of 60 x 25 cm when two cultivars and four intra row spacings were used.

In Cuba, Hernandez and Ortiz (1985) studied potato varieties Baraka and Desiree and found that yields increased with narrower spacings. Size composition was best at narrowest spacing of 65 x 20 cm. In a different study, Hernandez, (1982) obtained highest yields from 70 x 20 cm spacing and the number of small sized tubers increased with decreased spacing.

## 2.5 Plant Density Seed size and Dry matter Content

The ratio of total tuber dry matter to total (fresh) tuber weight is the percentage of dry matter in the tubers (Beukema and Van der Zaag, 1990). Burton, (1989) states that close spacing of potato plants resulted in a lower percentage of dry matter and attributed this to the shading expected when plants are closely spaced. However, Vokal and Radil (1996) found no effect on both yield and dry matter content when interrow spacings of 90 cm and 75 cm were used. Havecort, (1991) documented that potato plants grown from smaller seed tubers produced daughter tubers of lower dry matter content than those produced from larger seed tubers. He attributed this to the early establishment of the latter leading to accumulation of more dry matter.

# 3.0 MATERIALS AND METHODS

## 3.1 Location

The field study was carried out at Mt. Makulu Research Station in Agroecological region II of Zambia. This region receives about 750-1000 mm of precipitation per annum and is a major potato producing region in the country. The soil type of the location is *fine, mixed isohyperthermic udic paleustoll*.

## 3.2 Treatments and Design

Three potato varieties Up To Date, Baraka and Pentland Dell were used in this study. These varieties are all officially released in Zambia. Two interrow spacings of 75 and 90 cm with four seed sizes of 26-30 mm, 31-35 mm, 36-40 mm and 41-45 mm were imposed on each variety. Inter-row spacing was varied according to seed size as shown in table 1.

Table 1. The potato seed size and interrow spacing arrangement at Mt. Makulu in 1996/97 season.

| SEED SIZE (MM) | INTER-ROW SPACING (CM) |
|---|---|
| 26 - 30 | 20 |
| 31 - 35 | 25 |
| 35 - 40 | 30 |
| 41 - 45 | 35 |

The treatments were arranged in a split-split plot design replicated three times. Variety with three levels formed the main plots; interrow spacing with two levels formed the sub plots while seed sizes with four levels formed the sub-sub-plots. Each sub-subplot had four rows of 3.5 m in length.

## 3.3 Agronomic practices

The potatoes were planted manually on 4$^{th}$ January 1997 after presprouting by mini-chitting. Mini-chitting involves subjecting the seed potato to room temperature in diffuse light after cold storage. The change in temperature breaks dormancy and enhances sprouting while diffuse light ensures production of sturdy green sprouts. A weekly spray programme against insects and fungi was adopted beginning second week after emergence using Azodrin (a.i. 400g/litre) as insecticide and Bravo (a.i.500g/litre) as fungicide.

Hand hoes were used for weeding and ridging. Ridging was done twice, three and eight weeks after emergence respectively.

Due to a dry spell that lasted almost three dekads two months into the growing season, supplemental water was provided by means of furrow irrigation, applied three times a week for three weeks.

At 90 days, the plants were dehaulmed. This involves cutting off the haulms to reduce danger of transmission of virus diseases from the leaves to the tubers. This practice is particularly recommended in seed production. The potatoes were harvested manually over two days from 19$^{th}$ to 20$^{th}$ April 1997.

## 3.4 Data Collection

### a) Days of 50% Field Emergence

The number of days from planting to emergence of at least one stem of 50% of the sown tubers was recorded to determine emergence rate for each variety and seed size.

### b) Percentage Field Emergence (stand count)

Percentage field emergence was recorded from each treatment one month after planting to determine influence of seed size on emergence. The assessment was done basing on emergence of at least one stem from each of the planted tubers. The assessment of field emergence in this manner can only serve as a means of determining the survival rate (or mortality) of the planted tubers.

c) Number of main stems per square metre

The number of main stems per square metre was recorded one month after planting. This was done by counting the total number of main stems per sampled square metre in each treatment.

d) Tuber Yield

The weight of harvested potatoes from two middle rows was determined for each treatment. A distance of 0.25 m at both ends of the rows was discarded and not included in the analysis.

e) Daughter Tuber Sizes

The weights of different sizes of daughter tubers were determined by passing the potato tubers through grids of appropriate diameters. Four categories were considered: -

(i) Tubers greater than 50 mm

(ii) Tubers between 40 mm and 50 mm

(iii) Tubers between 30 mm and 40 mm

(iv) Tubers less than 30 mm

*This aspect is important in determining the marketable yield for different purposes.*

f) <u>Dry Matter Content</u>

The dry matter content of *sample tubers from each treatment* was determined to assess influence of size of seed tuber and spacing on dry matter content of daughter tubers. Determination of dry matter was done using the oven method designed and proposed by the German-Dutch working group - Standardization. This involves crushing a sample into pulp and pre - drying it for 15 hours at a temperature of 60 degrees and then further dry it for three hours at 105 degrees. The resulting weight loss is then used to calculate dry matter content of the tubers (EAPR, 1995).

## 3.5 Data Analysis

All parameters determined were subjected to Analysis of Variance and Mean Separation using the LSD Test. A gross margin analysis was done on the tuber yield to determine the combination of the factors that would give the highest economic returns. In carrying out this analysis, it was important to establish the relationship between seed tuber size and tuber weight in order to ascertain seed requirements in terms of weight per hectare for the different seed size ranges at the applied spacing. Consequently, the seed cost per hectare is calculated for each treatment. The seed price for different seed sizes is based on the ratio in weight required to achieve similar stem densities. This is the recommended way of setting seed price for various seed sizes (wiersema, 1980). In this case, a ratio of 9:7:6:5 for 26-30 mm, 31-35 mm 36-40 mm and 41-45 mm respectively was used. To calculate crop value a wholesale price of K5,000 per 10 kg pocket was used.

# 4.0 RESULTS

## 4.1 Days to 50% Emergence

Varieties and seed sizes showed significant effects ($P \leq 0.05$) on the length of time from planting to 50% emergence. The interaction between variety and seed size was also significant. Up to Date emerged earliest (13.0 days) while Pentland Dell emerged latest (16.8 days). Larger seed sizes (36-40 mm and 41-45 mm) emerged earlier (14.1 days) than smaller seed sizes of 26-30 mm and 31-35 mm at 14.7 days and 14.5 days respectively. (Table 2).

Table 2: Days to 50% emergence for three varieties and four seed sizes of potato grown at Mt. Makulu in 1996/97 season.

| Seed Size (mm) | Up to Date | Baraka | Pentland Dell | Mean |
|---|---|---|---|---|
| 26-30 | 13.2 | 13.3 | 17.5 | 14.7 |
| 31-35 | 13.2 | 13.5 | 16.8 | 14.5 |
| 36-40 | 13.0 | 12.8 | 16.5 | 14.1 |
| 41-45 | 12.8 | 13.2 | 16.2 | 14.1 |
| **Mean** | **13.0** | **13.2** | **16.8** | |

LSD (0.05) Variety (A) = 1.0 CV (%) (A) = 9.01

LSD (0.05) Seed Size (c) = 0.3 CV (%) (C) = 2.97

LSD (0.05) (A X C) = 1.4 CV (%) (AXC) = 2.97

## 4.2 Percentage Field Emergence

Varieties were significantly different for percentage field emergence (Appendix B) Pentland Dell had a higher Percentage field emergence (96.98) than Baraka (93.26) but the differences between Pentland Dell and Up To Date and that between Baraka and Up to Date were not significant. (Table 3).

Table 3. Percentage Field Emergence for three potato varieties grown at Mt. Makulu in 1996/97 season.

| **Variety** | **Percentage Field Emergence** |
|---|---|
| Up to Date | 93.80 |
| Baraka | 93.26 |
| Pentland | 96.98 |
| **Mean** | **94.68** |

CV % = 4.87

LSD (0.05) = 3.68

The smallest seed tuber size (26-30 mm) showed a significantly lower ($P \leq 0.05$) Field emergence (89.52%) than the other sizes of 31-35 mm 36-40 mm and 41-45 mm which had field emergence of 94.74, 97.10 and 97.36 respectively. (Table 4).

Table 4: Percentage Field Emergence for four seed sizes of potato grown at Mt. Makulu in 1996/97 season.

| Seed Size (mm) | Percentage Field Emergence |
|---|---|
| 26-30 | 89.52 |
| 31-35 | 94.74 |
| 36-40 | 97.10 |
| 41-45 | 97.36 |
| **Mean** | **94.68** |

CV% = 4.28

LSD(0.05) = 3.36

## 4.3 Number of stems per square metre

The effect of variety and spacing on the number of stem per unit area are shown in Tables 5 and 6. The varieties showed significant difference ($P \leq 0.05$) in the number of stems per square metre. Variety Pentland Dell had a lower number of stems per square metre (17.33) than up to date and Baraka (24.25 and 24.46 respectively). Tuber seed size did not appear to affect the number of stems per square metre.

Table 5: Number of stems per square metre for three potato varieties grown at Mt. Makulu in 1996/97 season.

| **Variety** | **Stems per square metre** |
| --- | --- |
| Up to Date | 24.25 |
| Baraka | 24.46 |
| Pentland Dell | 17.33 |
| **Mean** | **22.01** |

CV% = 7.38

LSD (0.05) = 1.69

Spacing at 75 cm between rows had significantly ($P \leq 0.05$) more stems per square metre (23.69) than at 90 cm (20.64) (Table 6).

Table 6: Effect of Interrow spacing on the number of stems per square metre of potato grown at Mt. Makulu in 1996/97 season.

| **Interrow spacing (cm)** | **Number of stems per square metre** |
|---|---|
| 75 | 23.69 |
| 90 | 20.64 |
| **Mean** | **22.16** |

CV(%) = 12.84

LSD (0.05) = 1.28

## 4.4 Tuber Yield

Variety and spacing were found to have a significant effect ($P \leq 0.05$) on tuber yield (Table 7 and 8). Baraka had the highest yield (32.5 mt./ha) followed by Up to Date (28.9 mt./ha). Pentland Dell yielded least at 17.3 mt/ha. (Table 7).

Table 7: Tuber Yield of three potato varieties grown at Mt. Makulu in 1996/97 season.

| **Variety** | **Tuber Yield (mt/ha)** |
|---|---|
| Up to Date | 28.0 |
| Baraka | 32.5 |
| Pentland Dell | 17.3 |
| **Mean** | **26.2** |

CV(%) = 17.55

LSD (0.05) = 3.7

Spacing at 75 cm between rows produced significantly ($P \leq 0.05$) higher yield 27.5 mt/ha than at 90 cm (24.9 mt/ha) (Table 8).

Table 8: Tuber Yield at two spacings of Potato grown at Mt. Makulu in 1996/97 season.

| **Spacing (cm)** | **Tuber Yield (mt/ha)** |
|---|---|
| 75 | 27.5 |
| 90 | 24.9 |
| **Mean** | **26.2** |

CV (%) = 15.63

LSD (0.05) = 2.4

## 4.5 Dry Matter Content

Variety, spacing and seed size all had a significant effect ($P \leq 0.05$) on dry matter content of daughter tubers. Significant effects were also observed between variety and spacing and between variety and seed size.

Pentland Dell had the highest dry matter content of 20.70% while Baraka had the lowest of 16.62%. (Table 9). The largest seed size (41-45 mm) yielded tubers with higher dry matter content (18.83%) and this was significantly different ($P \leq 0.05$) from the other seed sizes. Seed size of 31-35 mm did not differ significantly in dry matter content from that of 36-40 mm at 18.51% and 18.44% respectively. The smallest seed size of 26-30 mm yielded tubers of lowest dry matter content of 17.76% which was significantly different with the other seed sizes (Table 9).

Table 9: The effect of seed size on dry matter content of three potato varieties grown at Mt. Makulu in 1996/97 season.

| Seed size (mm) | Dry matter Content (%) | | | |
|---|---|---|---|---|
| | **Up to Date** | **Baraka** | **Pentland Dell** | **Mean** |
| 26-30 | 17.60 | 15.58 | 20.12 | 17.76 |
| 31-35 | 17.92 | 16.93 | 20.20 | 18.40 |
| 36-40 | 17.78 | 16.88 | 20.87 | 18.51 |
| 41-45 | 17.77 | 17.08 | 21.63 | 18.83 |
| **Mean** | **17.76** | **16.62** | **20.70** | |

CV% (Variety) (A) = 1.91 LSD (0.05 = 0.23

CV% (Seed size) (C) = 1.88 LSD (0.05) = 0.23

CV% (AXC) = 1.88 LSD (0.05) = 0.49

Differential response of variety to change in dry matter content relative to seed size was evident for Baraka and Pentland Dell (Table 9). As seed size increased from 26-30 mm to 41-45 mm, dry matter content of Baraka increased from 15.58% to 17.08%.

A similar trend was observed in Pentland Dell in which dry matter increased from 20.12% to 21.63% Up to Date however showed no response to change in seed size (Table 9).

Table 10: The effect of interrow spacing on dry matter content of three potato varieties grown at Mt. Makulu in 1996/97 season.

| Spacing | Dry matter Content (%) | | | |
|---|---|---|---|---|
| | **Up to Date** | **Baraka** | **Pentland Dell** | **Mean** |
| 75 | 16.32 | 16.37 | 20.52 | 17.73 |
| 90 | 19.22 | 16.88 | 21.03 | 19.04 |
| **Mean** | **17.76** | **16.62** | **20.78** | |

CV (%) Variety (A) = 1.91 LSD (0.05) (A) = 0.23

CV (%) Spacing (B) = 0.70 LSD (0.05) (B) = 0.19

CV (%) (AXB) = 0.70 LSD (0.05 (AXB) = 0.26

Table 10 illustrates the responses in dry matter content of the three varieties to interrow spacing. Generally, there was an increase in dry matter from a narrower interrow spacing to wider spacings for all varieties. Pentland Dell at 75 cm interrow spacing had significantly ($P \leq 0.05$) more dry matter (20.52%) than both Baraka and Up to Date even when the latter are spaced at 90 cm between rows. (16.88% and 19.22% respectively).

## 4.6 Tuber Grades

Baraka significantly ($P \leq 0.05$) gave the highest percentage of tubers greater than 50 mm (41.73%) compared to Up to Date (36.13%) and Pentland Dell (14.74%) (Table 11).

Table 11: Percentage tubers greater than 50 mm in diameter for three potato varieties grown in Mt. Makulu in 1996/97 season.

| **Variety** | **Percentage Tubers > 50 mm diameter** |
|---|---|
| Up to Date | 36.13 |
| Baraka | 41.73 |
| Pentland Dell | 14.74 |
| **Mean** | **30.86** |

CV (%) = 21.23%

LSD (0.05) = 10.75

A wider spacing of 90 cm significantly ($P \leq 0.05$) yielded a higher percentage of tubers greater than 50 mm (34.98%) than a closer spacing of 75 cm (26.76%) (Table 12).

Table 12: Effect of spacing on tuber size (>50 mm diameter) of potato grown at Mt. Makulu in 1996/97 season.

| **Spacing (cm)** | **Percentage tubers >50 mm diameter** |
|---|---|
| 75 | 26.76 |
| 90 | 34.98 |
| **Mean** | **30.87** |

CV (%) = 16.60

LSD (0.05) = 5.81%

Significant differences for percentage of tubers between 40 and 50 mm were observed among varieties. Pentland Dell significantly ($P \leq 0.05$) produced a highest percentage of tubers in this category (52.81%) compared to Baraka (39.52%) and Up to Date (43.01%) (Table 13).

Table 13: Percentage tubers between 40 mm and 50 mm diameter of three potato varieties grown at Mt. Makulu in 1996/97 season.

| **Variety** | **Percentage tubers between 40 and 50 mm diameter** |
|---|---|
| Up to Date | 43.01 |
| Baraka | 39.52 |
| Pentland Dell | 52.81 |
| **Mean** | **45.14%** |

CV (%) = 17.70

LSD (0.05) = 6.39

The treatments imposed did not have any significant effect on tubers between 30 and 40 mm nor on that less than 30 mm.

## 4.7 Gross - Margin Analysis

The average weight of a tuber for each size range was used as the basis for determining seed requirement per hectare and consequently the seed cost per hectare. (Tables 14 and 15).

Table 14: Tuber sizes and corresponding weight

| Seed size (mm) | Average tuber weight (grams) | Number of tubers per kilogram |
|---|---|---|
| 26 - 30 | 15 | 66.7 |
| 31 - 35 | 29 | 34.5 |
| 36 - 40 | 60 | 16.7 |
| 41 - 45 | 79 | 12.7 |

Table 15: Seed Requirements and seed cost per hectare at different spacings.

| Seed Size | Row Spacing | No. of tubers required to plant a hectare | Seed required per hectare (25 kgs) | Seed cost per 25 kg | Total seed cost/ha (kg) |
|---|---|---|---|---|---|
| 26 - 30 | 75 | 66,500 | 40 | 36,000 | 1,440,000.00 |
| | 90 | 55,500 | 33 | 36,000 | 1,188,000.00 |
| 31 - 35 | 75 | 53,200 | 62 | 28,000 | 1,736,000.00 |
| | 90 | 44,400 | 51 | 28,000 | 1,428,000.00 |
| 36 - 40 | 75 | 44,289 | 106 | 24,000 | 2,544,000.00 |
| | 90 | 36,963 | 88 | 24,000 | 2,112,000.00 |
| 41 - 45 | 75 | 38,038 | 120 | 20,000 | 2,400,000.00 |
| | 90 | 31,746 | 100 | 20,000 | 2,000,000.00 |

The seed cost per hectare was about 17% lower when planted at 90 cm between rows compared to planting at 75 cm between rows in all seed sizes. This arises from the number of bags required to plant a hectare for the two interrow spacings. Seed cost per hectare increases with increasing seed size but declines slightly for the largest seed size (Table 15).

When it comes to gross margin analysis, variety Baraka gave the highest gross margin followed by Up to Date. The results also show that in all the three varieties, the highest gross margin is obtained from the smallest seed size (26 - 30 mm) planted at the narrowest spacing (75 x 20 cm) while the lowest margin is obtained from the largest seed size (41 - 45 mm) planted at a spacing of 90 x 35 cm, the difference in gross margins between these two sizes and spacing combinations being 15.4%, 12.9% and 35.6% for Baraka, Up to Date and Pentland Dell respectively. (Table 16)

**Table 16: GROSS MARGIN ANALYSIS**

| TREATMENT | TOTAL YIELD (TONS) | CROP VALUE (MILLION KWACHA) | SEED COST (MILLION KWACHA) | INCOME LESS SEED COST (MILLION KWACHA) |
|---|---|---|---|---|
| Baraka; 75 cm; 25-39 mm | 34.83 | 17.415 | 1.440 | 15.975 |
| Baraka; 75 cm; 35-40 mm | 34.83 | 17.415 | 2.544 | 14.871 |
| Baraka; 75 cm; 40-45 mm | 33.77 | 16.885 | 2.400 | 14.485 |
| Baraka; 75 cm; 30-35 mm | 31.93 | 15.965 | 1.736 | 14.229 |
| Baraka; 90 cm; 30-35 mm | 31.10 | 15.550 | 1.428 | 14.122 |
| Baraka; 90 cm; 25-30 mm | 30.30 | 15.150 | 1.188 | 13.962 |
| Baraka; 90 cm; 35-40 mm | 31.93 | 15.965 | 2.112 | 13.853 |
| Baraka; 90 cm; 40-45 mm | 31.03 | 15.515 | 2.000 | 13.515 |
| U.T.D.; 75 cm; 25-30 mm | 29.63 | 14.815 | 1.440 | 13.375 |
| U.T.D.; 90 cm; 25-30 mm | 28.80 | 14.400 | 1.188 | 13.212 |
| U.T.D.; 75 cm; 30-35 mm | 29.63 | 14.815 | 1.736 | 13.079 |
| U.T.D.; 90 cm; 30-35 mm | 28.77 | 14.385 | 1.428 | 12.957 |
| U.T.D.; 75 cm; 40-45 mm | 30.07 | 15.035 | 2.400 | 12.635 |
| U.T.D.; 75 cm; 35-40 mm | 29.20 | 14.680 | 2.554 | 12.056 |
| U.T.D.; 90 cm; 35-40 mm | 27.67 | 13.835 | 2.112 | 11.723 |
| U.T.D.; 90 cm; 40-45 mm | 27.30 | 13.650 | 2.000 | 11.650 |
| P/Dell; 75 cm; 25-30 mm | 19.33 | 9.665 | 1.440 | 8.225 |
| P/Dell; 75 cm; 40-45 mm | 20.80 | 10.400 | 2.400 | 8.000 |
| P/Dell; 75 cm; 35-40 mm | 19.83 | 9.915 | 2.544 | 7.371 |
| P/Dell; 90 cm; 25-30 mm | 15.57 | 7.785 | 1.188 | 6.597 |
| P/Dell; 75 cm; 30-35 mm | 16.27 | 8.135 | 1.736 | 6.399 |
| P/Dell; 90 cm; 35-40 mm | 16.57 | 8.285 | 2.112 | 6.173 |
| P/Dell; 90 cm; 30-35 mm | 15.17 | 7.585 | 1.428 | 6.157 |
| P/Dell; 90 cm; 40-45 mm | 14.60 | 7.300 | 2.000 | 5.300 |

# 5 DISCUSSION

Among the parameters observed, there was a strong cultivar effect particularly on days to emergence, percentage field emergence, plant density and tuber yield.

Pentland Dell emerged later than the other two varieties. Seed tuber sizes of 36-40 mm and 41-45 mm emerged earlier than sizes 26-30 mm and 31-35 mm. The late emergence of the variety Pentland Dell compared to the other two varieties (3-5 days later) may be attributed to the variety's genetic inability for sprouts to develop and therefore emerge quicker. The tendency by the largest seed to emerge earlier in Up to Date and Pentland Dell could be an indication that large seed size had the advantage of having extra reserves, which promoted quicker emergence. This fact was noted by Horton (1987) who observed that sprouts grow faster on large tubers because they have a greater food reserve available for each sprout than smaller tubers do. In variety Baraka however, seed size did not significantly affect the number of days to emergence. This could imply that even the small seed tubers are more vigorous in Baraka.

The tendency of smaller seed sizes to show a lower percentage field emergence indicates a lower survival rate than larger tubers. As Beukema and Van der Zaag (1990) observed, if growing conditions are adverse, a farmer should take precaution to plant the smaller seed sizes at a spacing that would compensate for the seed tubers that would be anticipated to die. Apparently this implies higher seed costs.

Variety and spacing had a significant effect on the number of stems per square metre (Table 5). The lower stem density of the variety Pentland Dell is a reflection of the poorly developed sprouts, which led to the production of many single stem plants.

Variety had a significant influence on the total tuber yield with Pentland Dell producing significantly lower yields than the other two varieties (Table 7). However, it would be in appropriate to infer that Pentland Dell is a lower yielder than the other two varieties because Pentland Dell in this study emerged late and had less developed sprouts at planting. In other words, the low stem density in the variety was manifested in the lower yields obtained. Not withstanding this however, both Baraka and Up to Date are reported to have better tolerance to a wide range of stresses. (Zamseed 1989)

In terms of spacing, 75 cm between rows produced relatively higher yields (27.51 mt/ha) than at 90 cm (24.89 mt/ha). Taleb et.al. (1973) and Smith (1977) observed that a closer spacing led to more plants per unit area and effectively to a certain extent higher yields. Therefore on account of yield alone and after a gross margin analysis, spacing at 75 cm between rows would appear to be the more favorable interrow spacing to use. Baarveld and Peeten, (1984), however noted that although a closer spacing gave a better distribution of stems, for technical reasons, the possibility of making good size ridges becomes limited so that tubers become exposed to sunlight causing greening of tubers and exposure to attack by potato tuber moth. However, if the extra seed costs do not supercede the extra income that is obtainable from this closer spacing as has been shown in this study, there should be other reasons for not recommending this spacing in preference to the 90 cm currently recommended in Zambia.

There are also some technical reasons that have been advanced by farmers such as adjustments for planters which are normally set at 90 cm. In this case, one needs to assess the cost benefit ratios. In fact most potato growers in Zambia plant their potatoes by hand and should therefore opt for this closer spacing if other considerations apart from yield are deemed not so important. Significant differences were observed in dry matter content among all the factors. The differences in the dry matter content among the varieties were expected and have implications on the end use of the product. Different genotypes have different characteristics and hence qualities. The effect of spacing on dry matter content in this study is notable in all varieties. This could be attributable to the effect of shading on dry matter accumulation as Burton (1989) observed. The earlier establishment of plants from larger seed size could have led to accumulation of more dry matter than in plants from the smaller seed size since harvest was done at the same time. This is in line with what was reported by Havecort (1991).

The implications of dry matter content on the cooking quality of potatoes is appreciated. While a reasonable amount of dry matter would suffice for domestic mashed or baked potatoes, those for production of starch, French fries and crisps need a fairly high dry matter content. The French fry and crisp industry for instance prefer dry matter contents of 20-24% since they contain a lower reducing sugar content and will therefore produce good quality product (i.e. no undesirable dark brown colour and bitter flavour) (Eijick et al, 1995). They further observed that potatoes with high dry matter content would use less oil during frying since less water has to be evaporated. From these observations, this will imply that for mashed or baked potatoes, variety Baraka would be preferred at a closer spacing with the smallest seed size used at planting. For the French fry (chips), crisp or starch industry, Pentland Dell would be preferred and for economic reasons, it would be better to plant the seed size 26-30 mm at a spacing of 75 x 20 cm as gross margin analysis shows. Consequently, this implies that for the other two varieties, in order to improve on dry matter content, it would be advisable to plant at a wider spacing if the French fry, starch or crisp industry is targeted. A lower dry matter content than expected especially in varieties Baraka and Up to Date was observed. This could be attributed to the rather wet conditions at the time of harvest. Namasiku (personal communication) observed that potatoes produced in the rainy season tend to exhibit a lower dry matter content than those produced in the dry season under irrigation.

The proportion of larger tubers was highest at the wider spacing (Table 11). This could be a result of greater competition at the closer spacing resulting in fewer assimilates available for each individual tuber. This was observed by Burton (1989) and Beukema and Van der Zaag (1990). The question of tuber quality in terms of size has far reaching implications which a farmer needs to take into account before deciding on which spacing to use. The desired size of the potato will depend on the intended use. Domestic cooking potatoes for example have different quality attributes from those of industrial processing. For French fries, tubers larger than 50 mm are preferred (Eijick et al, 1995) so that a wider spacing providing a higher percentage of such tubers than a closer spacing is desirable. On the other hand, for boiled or baked potatoes, the percentage of large tubers may not be particularly important in which case, a closer spacing should be preferred on account of higher yields. Other considerations with regard to size distribution may have to do with ease of harvest. It takes shorter time to harvest a crop where the percentage of large size tubers is high than where it is low (Prain, 1995). From the results shown in table 11, it is apparent that even though Baraka produced the highest percentage of tubers larger than 50 mm, it unfortunately had the least dry matter content (Table 9) so that for the frying industry, such seemingly antagonistic qualities need to be carefully considered.

From these results, it becomes apparent that consideration of which combination of variety, seed size and spacing to use will largely depend on the target market as all the factors have shown to affect both tuber size distribution and tuber quality in terms of dry mater content. Where preferences for a particular size or frying quality are not pronounced, it would be more economical to plant a closer spacing of 75 cm between rows for all varieties as this would yield higher returns. For growers who plant and ridge their potatoes by hand implements, and are targeting the domestic market, a closer spacing should even be more preferred because as mentioned earlier, there are no technical considerations such as adjustments for planters or possibility of making good size ridges. On the other hand, if potatoes are meant for the French fry or crisp production, then spacing at 90 cm between rows would be recommended if only to be assured of the market. This is particularly more important in a country such as Zambia where storage facilities for table potatoes are very limited if not non-existent as a result of which it becomes extremely risky to keep the produce for a long time without selling it.

# 6. CONCLUSION

Seed tuber size showed no significant influence on total yield of all three potato varieties used in the study although it was found that it would be more economical to plant the smallest seed size used (26-30 mm) at a spacing of 75 x 20 cm on account of spending less on seed and getting higher returns. A wider spacing of 90 cm between rows yielded potatoes of larger size with higher dry matter content, a combination that would be preferred for French fry and crisp production.

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## APPENDICES

### Appendix A. ANOVA for Days to 50% Emergence

| Source | Degrees of Freedom | Sum of Squares | Mean Square | F Value |
|---|---|---|---|---|
| Replication | 2 | 0.250 | 0.125 | 0.075 |
| Variety (A) | 2 | 210.583 | 105.292 | 63.175* |
| Error | 4 | 6.667 | 1.657 | |
| Spacing (B) | 1 | 0.222 | 0.222 | 1.2308 |
| AxB | 2 | 0.694 | 0.347 | 1.9231 |
| Error | 6 | 1.083 | 0.181 | |
| Seed Size (c) | 3 | 4.778 | 1.593 | 9.5556* |
| AxC | 6 | 2.972 | 0.495 | 2.9722* |
| BxC | 3 | 0.333 | 0.111 | 0.6667 |
| AxBxC | 6 | 0.417 | 0.069 | 0.4167 |
| Error | 36 | 6.000 | 0.167 | |
| **Total** | **71** | **234.000** | | |

Coefficient of Variation (%) = 2.97

**APPENDIX B:** **ANOVA for Percentage Field Emergence.**

| Source | Degrees of Freedom | Sum of Squares | Mean Square | F Value |
|---|---|---|---|---|
| Replication | 2 | 156.242 | 78.121 | 3.6698 |
| Variety (A) | 2 | 194.421 | 97.211 | 4.5666 |
| Error | 4 | 85.150 | 21.287 | |
| Spacing (B) | 1 | 9.245 | 9.245 | 0.2614 |
| AxB | 2 | 6.623 | 3.312 | 0.0936 |
| Error | 6 | 212.197 | 35.366 | |
| Seed Size (c) | 3 | 714.761 | 238.254 | 14.5049 |
| AxC | 6 | 96.054 | 16.009 | 0.9746 |
| BxC | 3 | 4.205 | 1.402 | 0.0853 |
| AxBxC | 6 | 132.010 | 22.002 | 1.3395 |
| Error | 36 | 591.325 | 16.426 | |
| **Total** | **71** | **2202.233** | | |

Coefficient of Variation (%)= 4.28

**Appendix C:** **ANOVA for Stems per Square Metre**

| **Source** | **Degrees of Freedom** | **Sum of Square** | **Mean Square** | **F Value** |
|---|---|---|---|---|
| Replication | 2 | 33.361 | 16.681 | 6.3211 |
| Variety (A) | 2 | 789.194 | 394.597 | 149.5316* |
| Error | 4 | 10.556 | 2.639 | |
| Spacing (B) | 1 | 136.125 | 136.125 | 17.0452* |
| AxB | 2 | 13.538 | 6.792 | 0.8504 |
| Error | 6 | 47.917 | 7.986 | |
| Seed Size (c) | 3 | 52.375 | 17.458 | 2.7071 |
| AxC | 6 | 12.538 | 2.097 | 0.3252 |
| BxC | 3 | 23.153 | 7.718 | 1.1967 |
| AxBxC | 6 | 25.972 | 4.329 | 0.6712 |
| Error | 36 | 232.167 | 6.449 | |
| **Total** | **71** | **1376.986** | | |

Coefficient of Variation (%) = 11.54

**Appendix D: ANOVA for Total Tuber Yield**

| Source | Degrees of Freedom | Sum of Squares | Mean Square | F Value |
|---|---|---|---|---|
| Replication | 2 | 137.704 | 68.852 | 3.2551 |
| Variety (A) | 2 | 3026.864 | 1513.432 | 71.5495* |
| Error | 4 | 84.609 | 21.152 | |
| Spacing (B) | 1 | 123.507 | 123.507 | 7.3672* |
| AxB | 2 | 13.239 | 6.619 | 0.3948 |
| Error | 6 | 100.586 | 16.764 | |
| Seed Size (c) | 3 | 13.994 | 4.665 | 0.2819 |
| AxC | 6 | 19.704 | 3.284 | 0.1985 |
| BxC | 3 | 20.987 | 6.996 | 0.4228 |
| AxBxC | 6 | 12.782 | 2.130 | 0.1288 |
| Error | 36 | 595.675 | 16.547 | |
| **Total** | **71** | **4149.650** | | |

Coefficient of Variation (%) = 15.52

**Appendix E: ANOVA for Dry Matter Content**

| Source | Degrees of Freedom | Sum of Squares | Mean Square | F Value |
|---|---|---|---|---|
| Replication | 2 | 0.316 | 0.158 | 1.2804 |
| Variety (A) | 2 | 220.961 | 110.480 | 895.7872* |
| Error | 4 | 0.493 | 0.123 | |
| Spacing (B) | 1 | 30.811 | 30.811 | 1774.7333 |
| AxB | 2 | 22.807 | 11.400 | 656.6659* |
| Error | 6 | 0.104 | 0.017 | |
| Seed Size (c) | 3 | 10.760 | 3.587 | 30.0291* |
| AxC | 6 | 5.866 | 0.978 | 8.1849* |
| BxC | 3 | 0.747 | 0.249 | 2.0849 |
| AxBxC | 6 | 5.656 | 0.943 | 7.8965* |
| Error | 36 | 4.300 | 0.119 | |
| **Total** | **71** | **302.819** | | |

Coefficient of Variation (%) = 1.88

## Appendix F: ANOVA for Tubers > 50 mm

| Source | Degrees of Freedom | Sum of Squares | Mean Squares | F Value |
|---|---|---|---|---|
| Replication | 2 | 1272.131 | 636.066 | 3.5067 |
| Variety (A) | 2 | 9739.785 | 4869.893 | 26.8481* |
| Error | 4 | 725.547 | 181.387 | |
| Spacing (B) | 1 | 1216.149 | 1216.149 | 11.6792* |
| AxB | 2 | 363.168 | 181.584 | 1.7438 |
| Error | 6 | 624.788 | 104.130 | |
| Seed Size (c) | 3 | 393.869 | 131.290 | 1.6538 |
| AxC | 6 | 1171.925 | 195.321 | 2.4604* |
| BxC | 3 | 128.835 | 42.945 | 0.5410 |
| AxBxC | 6 | 174.573 | 29.095 | 0.3665 |
| Error | 36 | 2857.879 | 79.386 | |
| **Total** | **71** | **18668.638** | | |

Coefficient of Variation (%) = 28.87

**Appendix G: ANOVA for Tubers Between 40 and 50 mm.**

| Source | Degrees of Freedom | Sum of Squares | Mean Squares | F Value |
|---|---|---|---|---|
| Replication | 2 | 1028.072 | 514.036 | 8.0183 |
| Variety (A) | 2 | 2279.201 | 1139.601 | 17.7764* |
| Error | 4 | 256.431 | 64.108 | |
| Spacing (B) | 1 | 279.267 | 279.267 | 2.2526 |
| AxB | 2 | 292.888 | 146.444 | 1.1812 |
| Error | 6 | 743.842 | 123.974 | |
| Seed Size (c) | 3 | 2.589 | 0.863 | 0.0116 |
| AxC | 6 | 375.474 | 62.579 | 0.8398 |
| BxC | 3 | 402.833 | 134.278 | 1.8019 |
| AxBxC | 6 | 311.479 | 51.913 | 0.6966 |
| Error | 36 | 2682.695 | 74.519 | |
| **Total** | **71** | **8654.771** | | |

Coefficient of Variation (%) = 19.14

**Appendix H: ANOVA for Tubers Between 30 and 40 mm**

| Source | Degrees of Freedom | Sum of Squares | Mean Squares | F Values |
|---|---|---|---|---|
| Replication | 2 | 15.629 | 7.814 | 0.0426 |
| Variety (A) | 2 | 2124.075 | 1062.038 | 5.7932 |
| Error | 4 | 733.301 | 183.325 | |
| Spacing (B) | 1 | 98.233 | 98.233 | 0.6971 |
| AxB | 2 | 10.222 | 5.111 | 0.0363 |
| Error | 6 | 845.461 | 140.910 | |
| Seed Size (c) | 3 | 254.722 | 84.907 | 2.6809 |
| AxC | 6 | 508.131 | 84.689 | 2.6740 |
| BxC | 3 | 54.325 | 18.108 | 0.5718 |
| AxBxC | 6 | 29.898 | 4.983 | 0.1573 |
| Error | 36 | 1140.177 | 31.672 | |
| **Total** | **71** | **5814.137** | | |

Coefficient of Variation (%) = 29.37

## Appendix I: ANOVA for Tubers < 30 mm

| Source | Degrees of Freedom | Sum of Squares | Mean Square | F Value |
|---|---|---|---|---|
| Replication | 2 | 1.747 | 0.873 | 0.1184 |
| Variety (A) | 2 | 55.948 | 27.974 | 3.7921 |
| Error | 4 | 29.507 | 7.377 | |
| Spacing (B) | 1 | 34.583 | 34.583 | 4.8091 |
| AxB | 2 | 0.188 | 0.094 | 0.0131 |
| Error | 6 | 43.148 | 7.191 | |
| Seed Size (c) | 3 | 4.718 | 1.573 | 0.7431 |
| AxC | 6 | 29.612 | 4.935 | 2.3319 |
| BxC | 3 | 2.169 | 0.723 | 0.3417 |
| AxBxC | 6 | 10.841 | 1.807 | 0.8537 |
| Error | 36 | 76.192 | 2.116 | |
| **Total** | **71** | **288.653** | | |

Coefficient of Variation (%) = 33.95

## Appendix J: Rainfall Data for 1996/97 Seasons

**Total Rainfall: 1040.8 mm**

**Records in millimeters**

| Date | November | December | January | February | March | April | May |
|---|---|---|---|---|---|---|---|
| 1 | | | | 0.3 | | 70.0 | |
| 2 | | | | 3.7 | | 4.1 | |
| 3 | | | 27.4 | 1.6 | 1.6 | 13.7 | |
| 4 | | 9.1 | 3.4 | | | 8.4 | |
| 5 | | | 15.6 | 4.5 | | | |
| 6 | | | 3.0 | 50.9 | | | |
| 7 | | | 1.3 | | | | |
| 8 | | | 41.4 | 2.3 | | | |
| 9 | | 2.7 | 1.0 | | 0.4 | | |
| 10 | | | 1.3 | 29.4 | | | |
| 11 | | 56.7 | | 17.2 | | | |
| 12 | | 22.6 | | 1.3 | | | |
| 13 | | 13.6 | 40.8 | 1.9 | | | |
| 14 | TR | 0.1 | 25.6 | 2.5 | | | |
| 15 | TR | 1.7 | 39.6 | 10.0 | | | |
| 16 | 0.9 | 7.0 | 5.6 | 27.4 | | | |
| 17 | 17.2 | 0.2 | 1.9 | | | | |

**Appendix J continued**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 18 | 1.4 | 0.5 | 4.5 | 44.6 | | | |
| 19 | 1.9 | 2.0 | 18.0 | | 21.9 | | |
| 20 | 14.2 | 1.4 | 11.6 | | | | |
| 21 | 0.4 | 7.6 | 22.0 | | 16.4 | | |
| 22 | 20.8 | 13.6 | 4.5 | | | | |
| 23 | | 3.6 | 37.0 | | | | |
| 24 | | 0.5 | 0.5 | | | | |
| 25 | | | 0.9 | | | | |
| 26 | | 9.6 | | 0.2 | | | 4.9 |
| 27 | 41.0 | 10.2 | | 4.4 | | | |
| 28 | 27.8 | | 11.3 | | | | |
| 29 | 5.8 | 1.9 | 28.3 | | | | |
| 30 | 2.2 | 1.1 | 9.8 | | 1.4 | | |
| 31 | | | 19.0 | | 2.3 | | |
| **TOTAL** | **133.6** | **165.7** | **374.0** | **203.0** | **44.0** | **96.2** | **4.9** |