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THE CASE OF OKASHANA I IN NAMIBIA

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Abstract

The pearl millet variety Okashana 1, developed jointly by ICRISAT and the Namibian national program, is grown on almost 50% of the national pearl millet area. ICRISAT and the Government of Namibia jointly obtained a 50% internal rate of return to public investments in the development and dissemination of this variety. The net present value of this return was more than US$ 11 million in 1998. The high level of return resulted from the use of germplasm originally developed by ICRISAT, thus cutting the time and costs involved in variety development and testing; the early involvement of farmers in varietal selection; rapid release in response to farmer preferences; and government commitment to the rapid multiplication and dissemination of high-quality seed. In sum, close collaboration between ICRISAT arid Namibian breeders and strong links with the Namibian farming community reduced research costs and speeded variety adoption. Continuing collaboration between the three partners led to the release of two additional pearl millet varieties in 1998. Both the new varieties have highly favorable prospects for adoption.

Résumé

L'impact des investissements dans la sélection des cultures: le cas de Okashana 1 en Namibie. La variété de mil Okashana 1, développée conjointement par l'ICRISAT et le programme national de la Namibie, est cultivée sur 50% de la superficie nationale consacrée au mil. L'ICRISAT et le Gouvernement de la Namibie ont obtenu ensemble un taux interne de rentabilité sur investissements publiques de l'ordre de 50% dans le développement et la diffusion de cette variété. La valeur nette actuelle de cette rentabilité a été plus de US$ 11 millions en 1998. Le taux élevé a été grâce à l'utilisation des ressources génétiques développées initialement par l'ICRISAT, réduisant ainsi le temps et les coûts liées au développement variétale et aux essais; à l'intervention des paysans dès le début de la sélection variétale, à la vulgarisation rapide en réponse aux préférences des paysans; et à l'engagement du Gouvernement à la multiplication et la diffusion rapide de semences de haute qualité. Ainsi, la collaboration étroite entre l'ICRISAT et les sélectionneurs namibiens, ainsi que des liens forts avec la communauté agricole namibienne ont permis de réduire les coûts de la recherche et de favoriser l'adoption variétale. La collaboration continue entre les trois partenaires a également permis de vulgariser deux variétés de mil en plus en 1998 qui ont des possibilités très intéressantes pour l'adoption.

The research activities reported here were carried out under the SADC/ICRISAT Sorghum and Millet Improvement Program (SMIP), supported by the United States Agency for International Development (USAID) and Bundesministerium fur Wirtschaftliche Zusammenarbeit/Deutsche Gesellschaft fur Technische Zusammenarbeit (BMZ/GTZ).

Impact from Investments in Crop Breeding: the Case of Okashana 1 in Namibia

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Impact of pearl millet breeding and variety selection in Namibia

Almost 80% of cropped area in Namibia is sown to one cereal grain—pearl millet (*Pennisetum glaucum*), which is the only crop adapted to the low rainfall and high temperatures characteristic of most parts of the country. Pearl millet, locally known as *mahangUy* is the staple food and the principal source of food security for the majority of the country's smallholders.

Pearl millet accounts for an estimated 24% of total calorie intake and roughly 40% of cereal grain intake by Namibian consumers (SADC Regional Early Warning Unit 1997). Namibia also produces small quantities of maize, largely under supplemental irrigation on a few larger farms. However, the country depends heavily on cereal grain imports. Maize, wheat, and rice are commonly imported, particularly from South Africa.

Improvements in pearl millet productivity are essential for both national and household food security. Each year, most Namibian farmers fail to produce enough grain to meet household consumption requirements. Limited rains and frequent droughts reduce average pearl millet yields to less than 400 kg ha^{-1}. In drier years, yields fall below 200 kg ha^{-1}. Farmers have coped with such risks by maintaining large grain stocks built up during the occasional season when rains are favorable. But in recent years, this practice has declined due to rising population density and a declining land resource base. Farmers are becoming increasingly dependent on grain purchases and government distributions under drought relief programs.

The main contribution of Namibia's pearl millet breeding program has been to provide farmers with earlier-maturing varieties that offer higher average grain yields, and a higher probability of harvest, when rainfall is poor. These varieties allow farmers who sow with the first rains to obtain a grain harvest 30 to 50 days earlier than is possible with traditional varieties. The new cultivars also allow farmers to sow late and still obtain a harvest. And multiple sowings help farmers distribute their labor more evenly over the cropping season and thus improve the timelines of sowing, weeding, and harvesting.

The value of these contributions is evidenced in the rapid adoption of Okashana 1 shortly after its release in 1989. By the 1996/97 cropping season, this variety was sown on an estimated 49% of the country's pearl millet area. Okashana 1 provides Namibia with an estimated 21,000 tons of additional pearl millet grain during the average harvest—an approximately 20% increase in total production. Two additional pearl millet varieties, Kangara and Okashana 2, were released in Apr 1998. The prospects for adoption of these new varieties are also favorable.

The internal rate of return to past public investments in the development and dissemination of new pearl millet varieties in Namibia is estimated to be 50%. This is at the higher end of the continuum of returns to investment in agricultural research measured in Africa (Karanga 1990, Sanders et al. 1994, Chisi et al. 1997). This success can be explained by three major factors. First, Okashana I was quickly identified from the nurseries of an international research program, ICRISAT, as suited to Namibia's needs and adapted to local agroecological conditions. Rather than having to develop a new variety from its own limited germplasm stocks, Namibia could quickly exploit ICRISAT's global germplasm base for pearl millet introductions. The use of this germplasm was strengthened by advisory assistance from ICRISAT's pearl millet breeders.

Secondly, national scientists had the foresight to consider the preferences of small-scale farmers from the earliest stages of the national variety selection effort. Farmers dependent on pearl millet production chose Okashana 1 from among the 50 entries in Namibia's first observation nursery, quickly recognizing the value of early maturity as a complement to their later-maturing traditional varieties. Only 3 years of joint researcher-farmer observation were necessary before the variety was released.

Finally, the rapid adoption of Okashana I was stimulated by public investments in seed production and dissemination. Donor and government support enabled seed to be rapidly multiplied, and sold through the national extension program. The success of these investments laid the foundation for the privatization of national pearl millet seed supply. A seed growers' cooperative has been established. Seed production and marketing subsidies are in the process of being withdrawn.

While the high rate of return offers an important justification for government and donor investments in agricultural research, less quantifiable gains also need to be acknowledged. The success of Okashana 1 has increased the confidence of the national research and extension services in their ability to promote technological change. In addition, small-scale farmers have started to demand even better varieties. However, larger yield gains continue to be constrained by the severity of the environment in the main cropping systems of northern Namibia. A strong foundation has been laid for the continuing pursuit of varietal and crop management improvements. Ongoing monitoring of investment returns can ensure this foundation continues to be used effectively.

Table 1. Distribution of smallholder population and pearl millet production in northern Namibia, 1997.

	Omusati	Oshana	Ohangwena	Oshikoto	Kavango	Caprivi
Number of farmers[1]	38,000	20,000	34,000	22,000	18,000	19,000
Pearl millet area ('000 ha)[2]	85.8	36.4	83.8	61.7	24.1	4.5

1.RDSP 1998
2. Namibia Early Warning and Food Information Unit 1997, 1998

Finally, Okashana 1 has led to a net improvement in the welfare of the majority of Namibia's pearl millet producers and consumers. Most of the additional production serves to reduce the cereal grain deficits commonly experienced by pearl millet farmers, and improve food security among smallholder families. The higher production also reduces the country's dependence on grain imports.

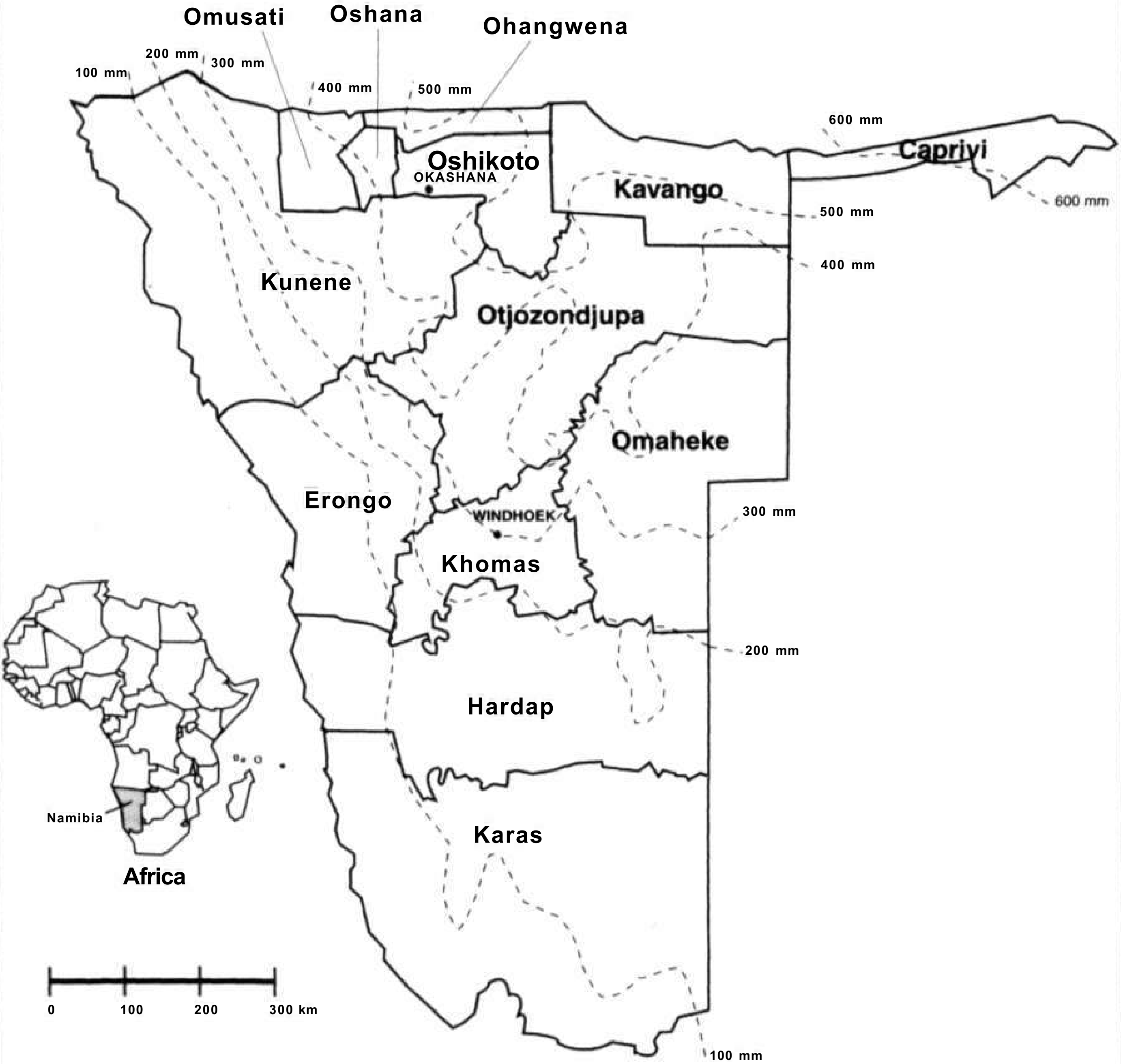
Pearl millet based farming system

Namibia's smallholder farming areas lie in six regions spread across the northern border area of the country: Ohangwena, Omusati, Oshana, and Oshikoto (which together constitute the area formerly known as the Northcentral Region[1]); Kavango; and Caprivi (Fig. 1). This area contains 60% of the Namibian population and virtually 100% of Namibia's small-scale farmers. Nearly all farmers (over 98%) in the Ovambo and Kavango regions grow pearl millet as their main staple (Table 1). Pearl millet production is also important in the Caprivi, though maize is the main grain crop grown in the far eastern river valleys.

Namibia's dry climate severely restricts the area suited to crop production and the types of crops that can be grown. Northern Namibia's smallholder farming regions receive 300 to 750 mm of annual rainfall during an Oct to Apr season, on a gradient from lower rainfall in the more densely populated west to higher and more secure rainfall in the eastern Zambezi river basin approximately 1200 km away. The remainder of the country is too arid for rainfed agriculture.

1. The term Northcentral Region is used in this report due to the lack of disaggregated data reflecting the current political boundaries. This region was formerly known as Ovambo or Ovamboland. In 1995 it was divided into Ohangwena, Omusati, Oshana, and Oshikoto.

Figure 1. Regions and rainfall distribution in Namibia.



Dotted lines represent rainfall isohyets (mm per year).
Omusati, Oshana, Ohangwena, and Oshikoto together constituted the former Northcentral region.

Between 1992/93 and 1995/96, rainfall in northern Namibia ranged from less than 200 mm in parts of the west to over 600 mm in the eastern tip of the Caprivi. While early rains can be expected in Oct, farmers generally wait for more consistent sowing rains in Jan and Feb. The season commonly ends in Apr. Only 3 months of the year have an average rainfall of more than 50 mm. Showers tend to be heavy—in the drier regions, one or two showers may account for over half the season's rainfall. Mid-season dry spells are common. Daytime maximum temperatures during the growing season commonly range between 35 and 40°C.

The pedology of Namibia is dominated by lithosolic, interior arenosolic, and poorly developed soil types. In the north, where rainfed agriculture is possible, the soils are predominantly sandy with limited water-holding capacity. As a result, cereal crops are commonly subject to severe moisture stress. Soil analyses indicate deficiencies in both nitrogen and phosphorus.

Surface water is virtually non-existent, with the exception of major rivers situated along the borders with Angola and Zambia. Groundwater is limited, and saline over extensive areas. Opportunities for supplementary irrigation are small.

Virtually all smallholder grain production is concentrated within a 50-km wide northern strip bordering Angola and Zambia. The smallholder economy is broadly characterized by a mixed crop-livestock production system (see Keyler 1995). More than 80% of households own livestock including cattle, donkeys, goats, or pigs. Two-thirds of households own at least two draft animals (oxen, bulls, cows, or donkeys) (Table 2). Almost 90% of the cropped area is sown to pearl millet. The remaining land is sown to small fields of sorghum, maize, cowpea, bambaranut, and groundnut. Pumpkin and melon are commonly grown as low-density intercrops with cereals.

Farm income is often supplemented by non-farm earnings. Almost 45% of farm households have access to income earned by family members working off the farm. A similar proportion of households has access to pension income. This includes 50% of all farmers in the more populous Northcentral region. Additional cash is earned from a wide range of non-farm sources including beer sales, fruit and vegetable sales, labor services, and crafts.

The average household has eight to nine members. Almost 40% of households are headed by women (Keyler 1995).

Table 2. Household characteristics of pearl millet fanners in northern Namibia, 1993.

	Northcentral region	Kavango
Average household size (number of members)	9.0	7.9
Percentage of households headed by women	44.0	22.0
Percentage of households with members employed off the farm	46.0	38.0
Percentage of households with pension income	50.0	23.0
Percentage of fanners growing various crops		
- pearl millet	100.0	100.0
- sorghum	95.3	79.3
- maize	76.0	99.3
- cowpea	95.3	96.0
- groundnut	82.0	66.7
Percentage of fanners owning at least 2 draft animals	60.0	66.0
Percentage of farmers owning a plow	56.0	58.0
Percentage of households who have ever sold pearl millet	26.5	71.5

Source: Keyler 1995

Table 3. Percentage of households using alternative crop management practices on pearl millet, 1996/97.

	Northcentral region		Kavango		Caprivi	
Apply fertilizer[1]	9.5		5.2		6.4	
Apply manure[1]	78.7		50.2		5.4	
Practice line-sowing[1]	16.3		7.9		71.5	
Use draft power[1]	Hand	20	Hand	<1	Hand	<1
	Draft animal	56	Draft animal	96	Draft animal	96
	Tractor	10	Tractor	13	Tractor	23
Average number of weedings[2]	Once	31.4	Once	30.8	Once	68.4
	Twice	51.3	Twice	69.2	Twice	31.6
	More than twice	16.6	More than twice	0.0	More than twice	0.0

1. Derived from preliminary data supplied by RDSP (1998)
2. Matanyaire 1996b

Most farmers pursue extensive crop management strategies (Table 3). Individual farmers may sow several times over the Oct to late Feb period depending on the timing and quality of rains. Most land preparation is done with draft power, but sowing tends to be performed by hand. Multiple seeds are sown, and then thinned to 1-4 plants per hill depending on the season. Farmers aim for 3-4 plants per hill with wide spacing (often 1 m or more) between hills. The national extension service is promoting line sowing as a means to reduce the labor required for weeding. This practice is being accepted by a growing proportion of households with direct access to extension support. However, data from a 1997 survey indicate only about 2% of Namibia's small-scale farmers have consistent access to extension advice on pearl millet management.

Almost 80% of small-scale farmers in the Northcentral region use manure, but application rates are low and the quality of manure is generally poor. About half the households in the Kavango region use manure.

Despite substantial price subsidies and strong promotion programs, less than 10% of smallholders use chemical fertilizer (Table 3). Early in the 1997/98 cropping season, the standard basal fertilizers available through the national extension service were priced 80% below the prevailing retail (private sector) market price. A 50 kg bag of 2-3-2 costs N$ 22 at the office of the extension worker and N$112 at private retail shops serving the large-scale farm sector. The subsidized price has not changed during the past 3 years. The limited interest, even in highly subsidized chemical fertilizer, compared with manure, suggests that farmers perceive investments in chemical fertilizer to be highly risky. Earlier surveys (e.g., Matanyaire 1996a, Keyler 1995) indicate up to 20% of farmers in both the Northcentral and Kavango regions have tried chemical fertilizer. But a more recent survey (1996/97 season) suggests that most of these farmers have rejected this input. In all likelihood, application levels will decline nearly to zero once the price subsidies are removed.

Though nutrient management is limited, most smallholders will invest in careful weeding. Despite low rainfall levels, two-thirds of all farmers in both the Northcentral and Kavango regions weed twice or more during the season. Such practices reflect farmer knowledge of the importance of limiting competition between weeds and crop plants for scarce rainwater.

Pearl millet production[2]

During the 1996/97 cropping season, Namibian farmers sowed 296,000 ha of pearl millet. Data available from the Namibia Early Warning and Food Information Unit (1998) indicate this area more than doubled during the 7 years since Independence in 1990 (Table 4). This increase has been attributed largely to the combined effects of post-Independence resettlement and smallholder population growth.[3]

The combination of low rainfall, frequent drought, and extensive crop management results in low average pearl millet yields in the smallholder farming areas. Between 1990/91 and 1996/97, national pearl millet yields averaged 100-360 kg ha^{-1} (Table 5). Yields tend to be highest in the Kavango region (ranging from 100 to 460 kg ha^{-1}) and lowest in the western parts of the Northcentral region (100-350 kg ha^{-1}).

The actual grain yield obtained by any particular farmer depends mainly on the timing and level of localized rainfall, the time of sowing, and the level of crop management. Individual farmers commonly use multiple sowing dates to reduce their production risks. But multiple sowings are also necessitated by frequent crop failures.

The low yields translate into low production levels relative to domestic cereal grain consumption requirements. Production data are summarized in Table 6. These estimates indicate northern Namibia has consistently faced a cereal grain deficit. Aggregate production has averaged only about one-half of the region's food grain requirement, which is estimated at a minimum of 130 kg per person per year. Northern Namibia produced over 80% of its cereal grain requirement in 1997, after a highly favorable harvest. In contrast, following the severe 1991/92 drought year, northern Namibia had to import up to 85% of its cereal grains.

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2. Available estimates of pearl millet production in Namibia need to be considered with care. Though efforts have been made to improve the quality of these estimates, the regional aggregates may underestimate the actual levels of sown area and yield.

   Farm surveys indicate that the national estimates published by the Namibia Early Warning and Food Information Unit underestimate the pearl millet area per household. For example, according to Matanyaire (1996b), the average area sown to pearl millet in northern Namibia is 3.5 ha per household. The mean for the Northcentral region was 3.1 ha compared with 4.1 ha for Kavango. However, the Namibia Early Warning and Food Information Unit (1997) estimated the national average to be only 2.1 ha per household.

   The National Early Warning Unit area and grain yield estimates have been used in the analysis for this impact assessment since these "official" national data offer a consistent record since Independence. Insofar as these data, in fact, underestimate production, area, and yields, the rate of return to national investments in pearl millet research has been underestimated.

3. The 80% increase in estimated pearl millet area between 1992/93 and 1993/94 also appears to represent a statistical aberration associated with efforts to improve the quality of national data collection.

Table 4. Area ('000 ha) sown to pearl millet by smallholders in Namibia, 1990/91 to 1996/97.

Season	Northcentral region	Kavango	Caprivi	National
1990/91	119.5	10.8	2.1	[redacted]
1991/92	139.2	12.5	2.4	[redacted]
1992/93	129.9	11.7	2.2	[redacted]
1993/94	237.1	21.3	4.0	[redacted]
1994/95	243.4	21.9	4.1	[redacted]
1995/96	241.4	21.7	4.1	267.2
1996/97	267.7	24.1	4.5	296.2

Shaded areas represent estimates derived from available national data and 1996/97 regional data. Unshaded areas reflect aggregated and disaggregated statistics officially reported.

Sources: Namibia Early Warning and Food Information Unit 1997, 1998

Table 5. Average pearl millet[1] grain yields ($t\ ha^{-1}$) in northern Namibia, 1990/91 to 1996/97.

Season	Northcentral region	Kavango	Caprivi	National
1990/91	0.4	0.3	0.3	[redacted]
1991/92	0.1	0.1	0.1	[redacted]
1992/93	0.2	0.3	0.5	[redacted]
1993/94	0.2	0.5	0.2	[redacted]
1994/95	0.1	0.3	0.3	[redacted]
1995/96	0.2	0.4	0.3	0.2
1996/97	0.4	0.5	0.4	0.4

1. Sorghum and pearl millet grain yield data are aggregated in national estimates. The actual yields of the two crops are not appreciably different.

Shaded areas represent estimates derived from available national data and 1996/97 regional data. Unshaded areas reflect aggregated and disaggregated statistics officially reported.
Sources: Namibia Early Warning and Food Information Unit 1997, 1998

Low production levels lead farmers to depend heavily on the wage and pension incomes earned by some family members in order to purchase grain. The volume of grain trade increases during the days after pension checks are issued. Farmers also rely heavily on cash income earned from non-farm activities and livestock sales.

Almost all grain purchases through the formal market in northern Namibia are of maize—either as grain, or more commonly as milled meal. According to data from the Namibian Agronomic Board, the country imported over 125,000 t of white maize following the 1996 harvest (Table 7). This compares with a total estimated pearl millet production of 56,600 t. These imports cost more than N$ 800 per ton. While maize imports were expected to decline following the 1997 harvest, the favorable level of production in 1998 appears exceptional.

Namibia also imports significant quantities of wheat, primarily for bread products sold in urban areas; bread is also rapidly growing in popularity in the rural areas. According to Keyler (1995), 50% of children in northern Namibia state a taste preference for bread, compared to other cereal products including pearl millet meal. Available estimates indicated Namibia imported about 29,000 t of wheat during the 1996/97 marketing year and was prepared to import 35,000 t during the 1997/98 marketing year (SADC Regional Early Warning Unit 1997, 1998).

Table 6. Pearl millet production ('000 t) in northern Namibia, 1990/91 to 1996/97.

Season	Northcentral region	Kavango	Caprivi	National	Production, kg per capita[1]
1990/91	40.4	4.7	0.9	46.0	70.1
1991/92	13.2	1.5	0.3	15.0	20.2
1992/93	32.3	3.7	0.7	36.7	49.6
1993/94	52.0	6.0	1.1	59.1	75.8
1994/95	32.6	3.8	0.7	37.1	43.5
1995/96	49.8	5.8	1.1	56.6	66.1
1996/97	94.7	11.0	2.0	107.7	115.6

1. Calculated using the populations of Caprivi, Kavango, and the Northcentral region derived from 1991 census data and a 3.5% annual population growth rate.

Shaded areas represent estimates derived from national data and 1996/97 regional data. Unshaded areas reflect aggregated and disaggregated statistics officially reported.

Sources: Namibia Early Warning and Food Information Unit 1997, 1998

Table 7. White maize imports to Namibia, 1990/91 to 1996/97.

Season	Quantity of grain imports ('000 t)	Total cost of grain imports (N$ million)	Unit costs of maize imports (N$ t->)	Exchange rate N$ to US$
1990/91	25.9	13.9	536	2.76
1991/92	25.0	15.3	612	2.85
1992/93	53.8	30.9	575	3.27
1993/94	86.2	59.8	694	3.55
1994/95	50.3	39.6	787	3.63
1995/96	113.8	85.4	750	4.29
1996/97	125.2	102.6	820	4.60

Source: Namibia Early Warning and Food Information Unit 1998

Table 8. Pearl millet production sufficiency in northern Namibia, 1987/88 to 1991/92.

Percentage of farm households buying grain	Frequency with which a household is unable to produce enough pearl millet to meet consumption needs		
	Every year	3 or 4 years out of 5	Less than 3 years out of 5
Percentage of farmers in the Northcentral region	32.8	56.1	11.1
Percentage of farmers in Kavango	38.1	47.5	14.4

Source: Rohrbach 1995

Table 9. Percentage of households participating in the market as pearl millet sellers, early 1990s.

	Never sell grain	Occasionally sell grain	Sell grain every year
Northcentral region	73.5	26.5	0.0
Kavango	28.4	54.3	17.2

Source: Rohrbach 1995

Pearl millet marketing

The massive grain deficit reflected in aggregate national data is mirrored in the view of local market activity provided by recent surveys. Most pearl millet farmers are net grain buyers rather than sellers; this is a common characteristic of farming systems in semi-arid regions throughout southern Africa. Surveys conducted by Keyler (1995) in 1992 and 1993 show that one-third of all households in the Northcentral and Kavango regions never produce enough pearl millet grain to meet family requirements (Table 8). More than 50% of households experience a production deficit three or four years out of five.

These findings correspond with statistics indicating 74% of farm households in the Northcentral region and 28% in Kavango never sell pearl millet grain (Table 9). Most of the remaining farmers sell grain only occasionally. Less than 4% of farmers in the two main production regions consistently sell pearl millet grain each year. These tend to be larger farmers who sow at least 20 ha of the crop.

According to detailed farm survey data collected in Dec 1992, seven months after the 1992 harvest, roughly three-quarters of all households in the Northcentral and

Kavango regions were purchasing grain (Table 10). The largest proportion and quantity of purchases consisted of maize meal. Retail purchases of imported maize grain and meal on the formal and informal markets accounted for more than two-thirds of the total quantity of grain and meal traded (Rohrbach 1995).

Depending on rainfall, maize accounts for 10-70% of total cereal grain consumption. Farm households are also resolving their production deficits with increasing purchases of bread, noodles, and rice.

Most farmers profess a strong taste preference for pearl millet. During the 1992 surveys, 77% of farm household heads interviewed in the Northcentral region and 94% in Kavango, expressed a taste preference for pearl millet over maize. But preferences are changing rapidly. The majority of children interviewed in 1992 expressed a preference for bread and related wheat-based products (Keyler 1995).

In this food-deficit economy, market institutions have developed primarily for the purpose of importing and selling grain. Reliance on grain imports has also been encouraged by the efficiency of wholesale and retail distribution chains for maize, wheat, and rice products. Retail trading outlets *(cuca* shops) are widely dispersed and consistently stocked with maize meal. Bread sales are common, particularly in the Northcentral region.

According to the Apr 1993 surveys (Keyler 1995), virtually all farm households in the Northcentral and Kavango regions reported they had ready access to maize meal, and almost 90% had access to rice. In comparison, only 45% of farm households in the Northcentral region, and 44% in Kavango, reported they had ready access to pearl millet grain in the local market.

Most pearl millet is traded as grain through traditional village and city markets. During the 1993 survey period, a few formal traders stocked pearl millet grain, and many indicated an interest in expanding their business. But these retailers complained that pearl millet supplies were uncertain and the levels of demand

Table 10. Grain purchases by farm households in northern Namibia, Dec 1992.

		Proportion of grain purchased (%)		
		Millet grain and meal	Maize grain and meal	Sorghum grain
Northcentral region	73.0	17.2	81.0	1.7
Kavango	83.3	33.1	64.7	2.0

Source: Rohrbach 1995

unknown. They perceived a higher risk in holding inventories over extended periods (Rohrbach 1995).

The second major factor limiting the development of the pearl millet market is the relative price. Price surveys conducted between Dec 1992 and Aug 1993 indicated that maize was consistently cheaper than pearl millet on the domestic market. These surveys revealed that commercially traded pearl millet *grain* was 15% more expensive than ground maize *meal* or *flour* in the Northcentral region. In Kavango, commercially traded pearl millet *grain* was over 25% costlier than maize *meal* Households facing both a food production deficit and a severe income constraint thus have a strong incentive to purchase the less preferred substitute (Keyler 1995).

Pearl millet is most likely to be traded competitively to maize after a favorable harvest such as that of 1997. A reconnaissance survey in Feb 1998 showed that eight months after the harvest, many larger pearl millet producers still maintained substantial grain inventories. Despite this, the price of pearl millet on the northern Namibian retail market remained higher than the price of imported maize. The landed cost of maize from South Africa was estimated at N$ 920 t^{-1} (Table 11), approximately US$ 182 t^{-1}. In comparison to this landed cost of N$ 0.92 kg^{-1}, the lowest price quoted for pearl millet in the Northcentral region was N$ 1.00 kg^{-1}. Prices in Kavango ranged from N$ 1.20 to N$ 1.40 kg^{-1} when sold in 50-kg bags. In the rural market, farmers were quoting prices as high as N$ 2.00 kg^{-1}.

A more relevant comparison is between the price of maize meal and the cost of pearl millet grain plus milling services. Retail prices for maize meal are highly variable in northern Namibia, depending on where the meal is purchased and what quantity is bought. One wholesaler in Rundu (in Kavango) was selling maize meal at the beginning of Feb 1998 at N$ 1.30 kg^{-1}. In the Northcentral region, maize meal at one of the more expensive retail shops was priced at N$ 1.63 kg^{-1}.

Table 11. Grain prices (N$ kg^{-1}) in northern Namibia, Feb 1998.

	Millet grain (50 kg bag)	Millet grain (16 kg bucket)	Maize grain (50 kg bag)	Maize meal (50 kg bag)
Oshakati (Northcentral)	1.00	0.94-1.13	0.92	1.63[1]
Rundu (Kavango)	1.20-1.40	2.00	na	1.30
Katima Mulilo (Caprivi)	1.00	na	0.80	na

na = not available
1. High-priced retail supermarket

Alternatively, a consumer could purchase 50 kg of pearl millet grain for N$ 1.00 kg^{-1}. But to have this grain dehuiled and hammer-milled he would still have to pay N$ 1.06 kg^{-1} (the lowest price available in the Northcentral region in early Feb 1998, according to price surveys by the Mahangu Intelligence Unit of the Namibian Agronomic Board).

During a normal year, when grain deficits are high, maize prices set an effective ceiling on the market. Though farmers have a taste preference for pearl millet, they will not pay the 20-25% premium over the maize price.

Unexpectedly, a similar price premium seems to be maintained even when pearl millet supplies are high. Producers seem prepared to maintain their pearl millet stocks in the hope of obtaining more favorable prices—possibly in future years of drought. Larger producers complain to the government about marketing constraints. Yet they have difficulty in selling grain because they are unwilling to reduce their prices. In effect, the larger farmers are lobbying government to establish price supports, while holding grain in the expectation of future sale at premium prices.

As a result of these price relationships, poorer households tend to rely on maize meal to resolve their production deficits in both good and poor years. Only wealthier wage earners are willing to pay the premium price for millet.[4]

These market patterns significantly affect the rate of returns to investments in pearl millet research. Insofar as pearl millet productivity remains low, the main contribution of the additional production is to reduce the quantity of maize that needs to be imported. This implies that the reference price for valuing pearl millet productivity increases is the cost of maize in the rural market. Namibia must ultimately aim to produce pearl millet at a cost lower than the price of imported maize. Otherwise, the demand for pearl millet grain will remain limited.

Introduction of Okashana 1

Namibian research on pearl millet varieties was initiated during the 1986/87 cropping season with the establishment of a 0.25-ha observation nursery by the Rossing Foundation. Rossing hired an agronomist, W R Lechner, to develop a Research and Training Centre at Okashana, about 90 km southeast of Ondangwa,

4. These price and consumption patterns have important policy implications for possible market interventions by the government. Pearl millet price supports or special government purchases for grain stockholding schemes favor a few larger producers but hurt consumers.

on the southern, and drier, fringes of the Northcentral region. The Centre was built on land contributed by the Paramount Chief of Ovambo. Lechner visited ICRISAT's regional Sorghum and Millet Improvement Program (SMIP)[5] in Aug 1986 to collect a range of pearl millet varieties for initial testing. The ICRISAT breeder, S C Gupta, provided 50 varietal lines, including the variety ICTP 8203 (Rai et al. 1990). This pearl millet nursery was sown on some of the first land cleared for the Research and Training Centre.

The 1986/87 season was characterized by very low rainfall; the Okashana research site received only about 190 mm. Nonetheless, a field day was organized in Mar 1987 for about 120 farmers, to provide them with an early opportunity to assess the introduced germplasm. These farmers were gathered with the assistance of nearby church groups, but they had to find their own way to the research station. About half the participants were women.

To obtain farmers' perceptions of the alternative varieties, each participant was encouraged to vote for the best-looking cultivar. In an early example of participatory research techniques, each farmer was given a single piece of paper and asked to place it in one of the paper bags set up in front of each of the 50 lines. Almost 80% of the farmers voted for ICTP 8203, an early-maturing, bold-seeded variety that displayed good productivity despite the poor season.

In response to this interest in ICTP 8203, the Rossing Foundation requested ICRISAT to provide assistance with seed production. SMIP was asked to multiply enough seed for taste tests and a wider range of performance trials during the next cropping season. ICRISAT initiated seed production during winter 1987 at Muzarabani in northern Zimbabwe. About 50 kg of seed from this harvest was provided to the Rossing Foundation, and sown on 10 ha at Okashana during the 1987/88 season.

A second field day at Okashana in 1988 confirmed the preference of farmers for ICTP 8203. This field day included ICTP 8203 and a range of additional pearl millet lines supplied by ICRISAT. Farmers were now asked to select the 10 best varieties, and ICTP 8203 again headed the list. The full set of 10 varieties was combined with several local varieties to form a composite breeding population called NC 90.

Given the demand for ICTP 8203, 5-kg packets of grain obtained from the 1988 harvest were distributed to workers at the Okashana research station and to

5. SMIP is being implemented by ICRISAT under the auspices of SADC. The project has received financial support from USAID, BMZ/GTZ of Germany, and CIDA.

farmers in nearby villages for taste tests. In addition to providing data on local preferences, this distribution also encouraged farmers to experiment with the new variety. For example, the recipients included Maria Kaherero, a woman farmer who grew the variety, sought to further improve specific characteristics by making her own selections, and eventually provided germplasm back to the research program in the form of a cross between ICTP 8203 and her traditional landraces. The results of the taste tests were positive. Farmers liked not only the early maturity and large grain of the new variety, but also the ease of pounding and the taste.

Encouraged by this response, the Rossing Foundation initiated the multiplication of 4.5 t of ICTP 8203 during the 1988/89 season. This entire seed stock was quickly sold at an Oct 1989 field day at a subsidized price of N$ 1 kg^{-1}. In effect, the new variety, called Okashana 1 in recognition of its selection at the Okashana Research and Training Centre, had been "released". The variety was informally released by the Rossing Foundation because Namibia, still under South African control at that time, had no formal variety release procedures.

At a SMIP-sponsored regional workshop in 1989, ICRISAT offered a possible replacement for ICTP 8203, at the initiative of J R Witcombe, an ICRISAT breeder based in India. Several years of variety trials in India had proven the advantages of a new variety, ICMV 88908, over ICTP 8203. Both varieties were early maturing and bold seeded. However, ICMV 88908 offered a nearly 17% yield advantage over ICTP 8203, as well as a higher stover yield.[6] Namibia received 5 kg of ICMV 88908 from ICRISAT-Patancheru just prior to the 1989/90 season. This was sown on a 2-ha plot at the Okashana Research and Training Centre.

In Apr 1990, one month after Namibia's Independence, two SMIP scientists (Executive Director L R House and millet breeder S C Gupta) made their first formal visit to the Okashana research station. During this visit, Namibia's new Minister of Agriculture formally asked ICRISAT to help establish a new Namibian crops research program. ICRISAT was also formally requested to assist with the multiplication of Okashana 1.

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6. **The varieties ICTP 8203 and ICMV 88908 have similar parental germplasm. ICTP 8203 has parental material** originating in northern Togo. This was one of four parents of the Bold Seeded Early Composite (BSEC) population developed by ICRISAT in 1985, from which ICMV 88908 was derived. The other parents were from Ghana and India. Diverse germplasm of the desired plant type was added from both Africa and India through three generations of intermating and selection. Mass selection in the composite was initially applied for early flowering, panicle exsertion and size, grain size, and downy mildew resistance. Later, ICMV 88908 was produced by mass selection that targeted lateness of flowering in order to increase plant and panicle size. The variety was finally selected in 1988 after eight generations of recurrent selection carried out over a 4-year period. The first trials of ICMV 88908 were run in 1988, using seed from the penultimate generation.

   ICMV 88908 outyielded ICTP 8203 by nearly 17% in 29 replicated trials conducted by ICRISAT in India between 1989 and 1991. ICMV 88908 flowered in 48 days, a period similar to ICTP 8203. ICMV 88908 is a little taller than ICTP 8203. Panicles are thick, semi-compact to compact, lanceolate to cylindrical with a slight tapering toward the tip. Seeds are large (1000-grain mass >13 g) and rounded (Witcombe et al. 1995).

House and Gupta made a selection of heads from the ICMV 88908 plot for seed multiplication during the 1990 winter season in Zimbabwe. More than 10 t of seed was produced, packed into 2-kg lots, and shipped to Namibia for distribution to farmers at a cost of N$ 1 kg^{-1}. However, this time the sales were part of a government research initiative established at the Mahanene Research Station. In Oct 1990, Lechner, who was heading the Rossing Foundation's Okashana Research Centre, transferred employment to the Government of Namibia as head of the government's Mahanene Research Station. While the Rossing Foundation continued its own limited variety selection efforts for another year, the country's main pearl millet breeding program had shifted into government hands.

The Okashana 1 seed sales at the beginning of the 1990/91 season marked the introduction of ICMV 88908 as a replacement for ICTP 8203. Since the varieties were essentially similar, the variety name did not change. Most of this seed was sold to farmers near the Mahanene station both through direct sales and through NGOs.

Performance of Okashana 1

Available data quantifying the relative productivity of Okashana 1 are highly variable, as would be expected in the low-rainfall, drought-prone environments of northern Namibia. Grain yields from experimental trials range from 250 kg to over 2.5 t ha^{-1}. Much depends on the timing of sowing in relation to seasonal rainfall, and on crop management practices and related biases associated with the management of a small experimental plot.

The main advantage of Okashana 1 in the northern Namibian cropping system is its early maturity. This allows farmers greater flexibility in their management practices. Some farmers sow Okashana 1 at the beginning of the rainy season in order to obtain an early harvest, at the time when household grain stocks are low or exhausted altogether. In effect, these farmers are trying to reduce their purchases of maize grain or meal. For this strategy to be successful, farmers note that Okashana 1 must be harvested on a timely basis. If the harvest occurs too late, before the end of the rainy season, the grain turns dark in color. A timely harvest is also necessary to reduce losses due to stalk lodging. And finally, a few farmers indicated that if Okashana 1 is left in the field too long after maturity, it begins to germinate on the panicle if there is sufficient rainfall. Nonetheless, many farmers seem prepared to accept these risks in order to obtain food during the usual preharvest "hunger period".

However, most farmers seem to be pursuing a practice of sowing their longer-duration traditional varieties first (between Oct and Dec), with the early-season rains, and sowing Okashana 1 later, in Jan-Feb. This allows them to benefit from the yield advantages of their traditional varieties if rainfall is consistent through the cropping season. If the rains are late, a larger proportion of land would be sown to Okashana 1; if the rains are early, more land may be sown to traditional varieties.

The yield difference between early-sown traditional varieties and late-sown Okashana 1 is difficult to capture in the available data from experimental trials, because almost invariably the two varieties are sown in trials at the same time. Further, the trials tend to be better managed than the normal field crop—for example, higher plant density or more timely weeding. And small trial plots generally yield more than the surrounding fields.

The productivity gains included in this analysis are derived from a composite of trial results over the period 1992/93 to 1995/96. Many of these trial results are summarized in Annex 1. Four scenarios were considered:[7]

- Low or untimely rainfall without fertilizer
- Low or untimely rainfall with fertilizer
- Moderate or timely rainfall without fertilizer
- Moderate or timely rainfall with fertilizer.

The productivity associated with each scenario is outlined in Table 12. The data indicate that farmers may achieve a 25% increase in grain yield as a result of the early maturity of Okashana 1 in low-rainfall years without fertilizer. This considers the likelihood that even when part of the late-maturing traditional crop fails, Okashana 1 will still provide a harvest. Such poor rains are estimated to occur at least two out of every three years.

Both Okashana 1 and traditional varieties perform better (trial results suggest that yields can double) under more favorable conditions. While Okashana 1 outyields traditional varieties consistently by 25% without fertilizer, these data may underestimate the advantages of landraces during a longer rainy season. Long rains contribute to the production of more stover, a key input for feeding cattle.

7. These scenarios differ from those used by SACCAR in its 1995 impact assessment of the regional SMIP program. The SACCAR study (Anandajayasekeram et al. 1995) assumed rainfall differences coincided with regional boundaries, but the validity of this assumption is not evident in the post-Independence rainfall data.

Table 12. Estimated grain yield (kg ha^{-1}) superiority of Okashana 1 under variable rainfall conditions (yields are reduced by 30% to account for trial effects).

	Low or late rainfall	Moderate or timely rainfall
No fertilizer[1]		
Okashana 1	300	740
Local variety	240	590
Difference	+25%(60 kg)	+25% (+150 kg)
Fertilizer (15 kg P, 20 kg N ha^{-1})[2]		
Okashana 1	575	1530
Local variety	385	820
Difference	+49% (+190 kg)	+87% (+710 kg)

1. Data from farmer-managed trials in 1993/94 and 1994/95 for low rainfall, and researcher-managed trials in 1993/94, 1994/95, and 1995/96 for moderate rainfall.
2. Data from farmer-managed trials in 1994/95 for low rainfall and on-station trials with supplementary irrigation in 1994/95 for moderate rainfall.

Trial results suggest that when fertilizer is used, Okashana 1 may outyield local varieties by 50-90%. However, available survey data indicate that less than 10% of farmers use this input. Despite price subsidies equivalent, in recent years, to 80% of the farmgate price, fertilizer application rates are generally low. Most farmers who apply fertilizer use only a basal application. While more than 50% of small-scale farmers use manure, application rates are low. The "with fertilizer" scenarios are therefore based on results from experimental trials using 15 kg P_2O_5 and 20 kg N ha^{-1} (Annex 1).

The rate-of-return analysis presented below considers the value of Okashana 1 productivity gains without fertilizer. This scenario is considered more indicative of smallholder farming practices and of the productivity gains actually obtained from the new variety.

Seed multiplication

The multiplication and distribution of Okashana 1 (ICTP 8203) seed started quickly, slowed, and then started in earnest. The first significant multiplication occurred during the 1988/89 season, immediately following the expression of interest in the variety by small-scale farmers. The Rossing Foundation established a 10-ha seed plot at the Okashana Research and Training Centre, on which 4.5 t of seed were produced for distribution to farmers in 1989.

In response to a request from the Namibian government, SMIP assisted with the initial large-scale multiplication of the new Okashana 1 variety, ICMV 88908, during winter 1990. This seed was distributed to farmers during the 1990/91 sowing season.

Seed production then seems to have stopped, except for breeder seed for use in experimental trials. SMIP provided consistent support with the provision of Okashana 1 breeder seed through the 1997/98 sowing season (SMIP has consistently provided 50-100 kg of breeder seed each year for trials and foundation seed production in Namibia). However, no further "commercial" seed was produced until winter 1992, when an emergency seed production program was established in order to provide seed for drought relief programs following the poor 1991/92 season.

The growing demand for pearl millet seed, both from the government of Namibia and from farmers, emphasized the need for a more sustainable seed multiplication and distribution system. ICRISAT increased its efforts to develop the capacity of the national breeding program to maintain stocks of both breeder and foundation seed. In 1993, the government launched a project under which small-scale farmers produced Okashana 1 seed under the guidance of the Chief Crops Research Officer of the Mahanene Research Station. The national extension service contributed one officer to help monitor on-farm seed production. The Food and Agriculture Organization (FAO) and the European Union provided approximately US$ 70,000 for seed testing and processing equipment and to establish a N$ 150,000 revolving fund used to expedite payment to seed growers. In addition, GTZ provided a grant for seed packing equipment worth about N$ 85,000.

This program is a good example of successful small-scale seed production in southern Africa. The experience was highlighted in a Mar 1997 international conference on seed production (Lechner 1997) and in an Apr 1998 workshop on participatory research for sorghum and pearl millet scientists in southern Africa.

Farmers who participated in the 1993/94 season pilot scheme were selected through consultations involving several agencies. The process began with a meeting between research and extension staff and farmers interested in growing seed in the Omusati region of Northcentral Namibia (Lechner 1996, 1997). The farmers were identified by extension staff in the region. The objectives of the project were explained and farmers interested in participating were asked to register. About 50 farmers did so. The project staff then interviewed these farmers regarding their knowledge of pearl millet agronomy, and visited all potential seed fields to check isolation distances and soil fertility. Ultimately, 34 farmers were chosen for the first year of seed production (Table 13). During the second season, 76 farmers participated; by the 1996/97 season the scheme had grown to involve 112 small-scale farmers.

Under the small-scale seed production project, each seed producer is required to purchase foundation seed from the Mahanene Research Station. Farmers can then choose what level of inputs to apply to their crop. Project staff visit fields, if possible, twice each season to ensure the crop is well maintained and that rogueing is completed on time. Once a harvest can be estimated, participating farmers are given a "field certificate" indicating the estimated field size and production level. The seed project offers threshing services at cost. Immediately upon delivery to the Mahanene Research Station, the seed is cleaned and weighed. Samples are taken for germination testing and the farmer receives payment for 70% of the seed price. The balance is paid before the end of the year after deducting processing costs and service fees.

Seed may be rejected during the course of the season, or at the point of delivery, if fields are contaminated or if the source of foundation seed cannot be validated. Substandard seed is returned to the farmer for his or her own consumption. As a result, farmers have no incentive to deliver dirty or poor-quality seed. During the first three years of the scheme half to two-thirds of the seed producers failed to deliver seed of acceptable quality. The most common reasons were failure to rogue, resowing with seed of unknown origin, and drought.

During the first year (1993/94) of the seed project, 21 t of clean Grade 1 seed were produced. In the 1996/97 season, the small-scale farmers delivered 245 t of high-quality seed. The seed producers are paid N$ 2 kg^{-1}, about 50% higher than the prevailing market price for pearl millet grain in the Omusati area. Since average

Table 13. Number of farmers participating in pearl millet seed production, 1993/94 to 1996/97.

Season	Number of farmers applying to produce seed	Number of successful seed producers
1993/94	34	17
1994/95	76	35
1995/96	104	59
1996/97	112	94

grain prices have shown little change through the mid 1990s, this remains enough of an incentive to attract additional seed producers. Seed is then sold to other farmers at an ex-Mahanene price of N$ 3 kg^{-1}. The N$ 1 kg^{-1} margin covers most of the processing and packing costs, but does not fully cover the capital and staff costs of the project. Full cost recovery would require an ex-Mahanene price of N$ 5 kg^{-1}.

By the 1995/96 season, the project had grown too large to be effectively managed by the Chief Crops Research Officer at Mahanene. He encouraged the formation of the Northern Namibia Farmers Seed Growers Cooperative in 1996. A manager for the Cooperative was hired in Jan 1997. The cooperative was formally certified under the government's new cooperatives registration bill in May 1997.

Between 1991/92 and 1996/97, Okashana 1 seed was distributed through the national extension service. Distribution was free of charge in only 1 year—under the drought relief programs of 1996. In all other years farmers had to purchase the seed. Sales were made by extension workers from their offices.

Beginning in the 1997/98 season, seed sales were taken out of the hands of the extension service and made through the private sector. In Kavango and Caprivi, wholesale trade arrangements were established with Hygrotech, a large firm trading in agricultural inputs. In the Northcentral region, sales are being promoted by the Cooperative Manager through a wider range of wholesale and retail channels. Efforts are under way to ensure that a retail outlet is established near each extension worker.

Retailers receive Okashana 1 seed at an ex-Mahanene price of N$ 3 kg^{-1}, and are free to mark up the price before they sell. Price checks run in early Feb 1998 indicated retail prices of N$ 5-7.50 kg^{-1}. In comparison, hybrid maize seed is priced at N$ 18 kg^{-1}.

Data on seed produced and distributed in Namibia are summarized in Table 14. Seed sales have grown sharply since the 1995/96 season, partly due to a government purchase of 76.9 t of Okashana 1 seed for free distribution under a national drought relief program during the 1996/97 sowing season.

In 1998, the Seed Growers Cooperative negotiated a management agreement with the government of Namibia. Under this agreement, all assets were transferred to the Cooperative, including the revolving fund for seed production and sale, which had grown to N$ 500,000 from the original N$ 150,000. In addition, the Cooperative now holds responsibility for maintaining a 100 t national pearl millet seed security stock; the cost of maintaining this seed stock will be fully borne by the government. In effect, the government agrees to purchase—at the full commercial rate of N$ 5 kg^{-1}—enough seed to replenish this stock immediately following each season's harvest.

This project serves as a model seed supply scheme for circumstances where the private sector is reluctant to make an investment. The main impact of government and donor intervention was to take on the risks of seed production prior to the establishment of a self-sustaining seed cooperative. The combination of government and donor investments undoubtedly speeded the adoption of Okashana 1.

The success of seed production with small-scale farmers also depended heavily on the maintenance of tight quality control on both production and processing. Farmers quickly learned to maintain close control over their seed crops when fields or harvested seed were rejected for contamination.

Finally, the establishment of a well functioning Seed Growers Cooperative would not have been possible without a pearl millet variety in high demand by small-scale farmers. What remains to be seen is whether farmers are willing to pay the full costs of pearl millet seed. The N$ 3 kg^{-1} price at the processing plant still needs

Table 14. Okashana 1 seed production and distribution, 1988/89 to 1997/98.

Season	Seed production (t): Research service	Seed production (t): ICRISAT[1]	Seed production (t): Farmers[1] cooperative	Seed distribution[2] (sales and drought relief) (t)
1988/89	4.5	0	0	0
1989/90	0	10.3[3]	0	4.5
1990/91	0	0	0	10.3
1991/92	8.2	28.0[3]	0	0
1992/93	37	0	0	36.2[4]
1993/94	38	0	21	11.5
1994/95	46	0	74	35.5[5]
1995/96	17	0	214	120
1996/97	21.4	0	244.6	216
1997/98	0	0	177 est	56

1. Does not include 50-100 kg of breeder seed produced annually by ICRISAT
2. Generally lags seed production by one season
3. Produced during winter 1990 and winter 1992
4. Does not include 80 t of "common pearl millet" seed imported from India for distribution after the 1991/92 drought
5. Does not include a sale of 35 t of Okashana 1 seed to Botswana

to be increased to N$ 5 kg^{-1} to cover the full capital and operating costs of the cooperative. The retail price for seed may correspondingly rise to nearly N$ 10 kg^{-1}. This will likely encourage more farmers to save seed from the previous year's harvest.

Okashana 1 adoption

When farmers were asked about the main reasons for their interest in Okashana 1, the most common response was its early maturity (Table 15). As indicated above, this allows farmers greater flexibility in their cropping system—allowing an earlier harvest when food supplies are short, or a later sowing if early-season rains fail. An associated benefit is a more even labor profile for crop management over the course of the season. Sowing, weeding, and harvesting labor allocations may be extended over a period of weeks rather than days.

Grain yield, grain size, and drought tolerance were also cited as priority traits. The explicit value attached to the large grain of Okashana 1 is difficult to determine. Some farmers explain that the larger grain discourages birds from attacking the crop. They claim birds prefer the smaller-grained traditional varieties. Some argued that the larger grain eases dehulling and processing into flour; but an equal number complained that Okashana 1 was difficult to process. One associated benefit inferred from farmer interviews is that varieties with thicker panicles and larger grains simply look better in the field. This may improve a farmer's standing in the community.

While drought tolerance may be partly associated with the early maturity of Okashana 1, farmers also comment on its ability to withstand mid-season dry spells and low rainfall levels. Farmers perceive, at least, that this variety is more resistant

Table 15. Percentage of households identifying alternative grain traits as the most important justification for adoption (top 5 traits only), 1992/93 season.

	Northcentral region	Kavango
Early maturity	45.3	30.4
Grain yield	18.6	18.7
Grain size	15.1	21.5
Drought tolerance	14.0	15.3
Grain color	7.0	13.9

Source: Friis-Hansen and Rohrbach 1993

to the range of different types of drought they commonly face—short seasons, limited rainfall, and mid-season dry spells.

Farmers asked to summarize the greatest weaknesses of Okashana 1 have commonly and consistently cited three problems. The greatest problem is its weak stem, which causes plants to lodge at the end of the season. The problem is more pronounced if the crop experiences late rains. Pearl millet stalks are commonly used as fencing material and sometimes for roofing thatch. The weak stem reduces the value of Okashana 1 stalks as building and fencing material.

The second (and related) problem is low stover yield. This is particularly a concern in the Northcentral region, where population densities of both people and cattle are higher and the agroecology is drier. Farmers need high-value stover to feed their animals through the dry season and to strengthen cattle and donkeys for plowing services.

The third commonly cited problem with Okashana 1 is the softness of the grain. The softness makes it easier to pound grain into flour, but increases its susceptibility to storage pests such as weevils, and thus severely reduces the storability of the grain compared with traditional varieties. This leads farmers to consume or sell their Okashana 1 grain first, and maintain traditional varieties for longer-term grain stocks. If the harvest is poor, the susceptibility of the variety to storage pests is less of a problem. However, farmers interested in maintaining multi-year grain stocks face a greater constraint. In this case, the softer grain of Okashana 1 likely contributes to higher storage losses.

Farmers also commonly complain about the gray flour, which turns darker when Okashana 1 is boiled to produce the main staple dish of stiff porridge. Yet flour color alone is not viewed as a major impediment to adoption.

Some farmers complain about Okashana's tendency to shatter—the pericarp breaks into small pieces that are difficult to winnow from the flour—during the process of dehulling. This makes dehulling difficult and can worsen the taste of the flour. While clean flour is said to taste sweet, poorly processed flour can taste bitter. Differences in grain processing techniques may explain why some farmers claim to prefer the taste of Okashana 1 flour while others prefer their local varieties.

Two adoption rates for Okashana 1 were ultimately employed in the impact analysis (Table 16). The first rate assumes that all the Okashana 1 seed being sold was sown, and that 75% of the area sown to this variety during the previous year was sown the following season using farm-saved seed. This scenario suggests a

Table 16. Okashana 1 seed distribution and adoption, 1990/91 to 1996/97.

Season	Okashana 1 area as % of total pearl millet area[1]	
	Based on seed sales only, assuming no farm-saved seed is used	Based on seed sales and the assumption that 75% of previous year's Okashana 1 area was resown with farm-saved seed
1990/91	1.1	1.1
1991/92	2.3	3.1
1992/93	8.9	11.2
1993/94	3.0	11.4
1994/95	9.8	18.4
1995/96	16.2	30.0
1996/97	26.9	49.4

1. Area calculated on the basis of seed use (purchased and farm-saved), assuming a seed rate of 2.5 kg ha^{-1}

steady increase in Okashana 1 area, ultimately rising to 49% of the national pearl millet area in 1997. This level and rate of adoption was confirmed in interviews with farmers and extension agents during the Feb 1998 reconnaissance survey.

Nonetheless, a second, more conservative, adoption scenario was also considered in order to account for the unhappiness expressed by farmers with certain cultivar traits. Under this scenario the adoption rate each year was assumed to coincide with the level of Okashana 1 seed sales in that season; it was assumed that farmers did *not* resow seed obtained from a previous year's harvest.

Continuing crop improvement

Pearl millet is the only crop for which Namibia maintains its own breeding program. However, the national pearl millet improvement program has concentrated on developing the capacity to use genetic materials available from regional and international sources. The breeding program maintains particularly close links with ICRISAT and the US-based International Sorghum and Millet Collaborative Research Support Program (INTSORMIL).

The general objective of the national breeding program is to produce a range of improved varieties for evaluation in national variety trials and for eventual release to farmers. In Apr-May 1991, ICRISAT assisted with the collection of pearl millet germplasm sown across the major farming regions of the country (Appa Rao et al. 1991). This collection continues to provide base material for selection and variety development.

Around the time of this collection mission, S Ipinge was hired as the national pearl millet breeder. He took primary responsibility for Namibia's pearl millet trials during the 1994/95 season, and took leadership of the Okashana Research Station when it was taken over by the Namibian government in 1996.

After Okashana 1 was multiplied and distributed, adoption levels and constraints were monitored in a series of formal and informal surveys by breeders and economists (Friis-Hansen and Rohrbach 1993, Matanyaire 1996b). By 1993, farmer concerns about the weak stem and soft grain were widely acknowledged. In consequence, breeding and variety selection was targeted at identifying new cultivars with improved plant and grain traits. Ipinge's program focused mainly on breeding open-pollinated varieties, but he also initiated testing of pearl millet hybrids.

The national program again benefited from the efforts of the regional SADC/ ICRISAT pearl millet breeding program to identify a variety with early maturity and a stronger stem (Ipinge 1997). The ultimate product, SDMV 93032, was developed by SMIP breeder E S Monyo. This variety was produced from a backcross derived from the Zimbabwean landrace variety SDGP 1514 and two pearl millet varieties from ICRISAT's bold-seeded early composite population, ICMV 88908 and ICMV 87901 (i.e., Okashana 1 and one of its parents). The landrace was selected for its strong stalks and hard, vitreous grain, while the two ICRISAT parents were selected for their early maturity and large grain. The new variety was named in 1993, after six seasons of selection over a 3-year period. SDMV 93032 was first tested by the Namibian breeding program during the 1994/ 95 season.

SMIP assistance was also sought in identifying a complement to Okashana 1 with whiter grain and flour. The ultimate selection, SDMV 92040, was derived from the combination of germplasm from southern Africa and Togo (received via the breeding program at ICRISAT-Patancheru). The Togolese germplasm was crossed with progenies from the SADC White Grain Composite Nursery. The selection process targeted plants with bold, white grain and early maturity (50-55 days to flowering). SDMV 92040 was named in 1991/92, and during the following 5 years, was further improved by removing weaker plants during the course of gridded mass selection.

Both SMDV 93032 and SMDV 92040 were tested in 40 researcher-managed on-farm and on-station trials across northern Namibia over the period 1992/93 to 1996/97. Mean yields from these trials are summarized in Table 17. The two new varieties offer grain yields comparable to Okashana 1 and 25-40% higher than local varieties. Both have a maturity period, plant height, and panicle length similar to Okashana 1. SMDV 93032 offers a 30% improvement in lodging resistance compared with Okashana 1. The grain is also harder, allowing farmers to store grain over a longer period. SMDV 92040 has shown a consistent 15% yield superiority over Okashana 1, and also performed well in processing and taste tests with small-scale farmers. The main advantage of this variety, apart from high yield, is its cream-white grain.

The national pearl millet breeding program has also retained an element of participatory research with small-scale farmers. In the pursuit of improvements to Okashana 1, women farmers from around the Mahanene Research Station were invited to evaluate grain size, grain color, processing and cooking quality, and taste of a range of new varieties in advanced testing at the station (Ipinge et al. 1996). The farmers were also asked to evaluate the relative production performance and grain yields of advanced breeding materials. They were specifically asked to compare Okashana 1 and SDMV 92040. Unfortunately, the corresponding data for SDMV 93032 are not available.

Table 17. Performances of the new varieties in researcher-managed on-farm and on-station trials, 1992/93 to 1996/97.

	Okashana 1	SDMV 92040	SDMV 93032	Local variety
Mean grain yield (t ha^{-1})	1.48	1.66	1.36	1.19
Days to 50% bloom	55	53	56	63
Plant height (cm)	167	162	169	206
Ear length (cm)	23	22	23	33
Plant lodging (%)	31.3	na	20.5	16.3
Grain color	light gray	cream white	light gray	na
Visual hardness score (1 = very soft, 4 = very hard)	2.1	2.0	3.0	3.7 (Mahanene)
Fraction of large grains (>2.6 mm)(%)	72.5	50.8	55.3	36.1 (Mahanene)

na = data not available
Source: Ipinge 1997

In the 1993 trial, 70% of the farmers judged SDMV 92040 to have larger grains than the local varieties (Table 18). This variety was rated better than Okashana 1 and the local variety in terms of grain color and ease of processing. It was also ranked similar to the local variety, and superior to Okashana 1, in terms of taste by almost all farmers.

As a result of agronomic performance and acceptance by farmers, both varieties were officially released by the government of Namibia in Apr 1998—SDMV 92040 as Kangara, and SDMV 93032 as Okashana 2.

Research and extension costs and returns

In order to estimate the rate of return to investments in pearl millet breeding in Namibia, and to the development and dissemination of Okashana 1 in particular, it is necessary to calculate the investment costs necessary to get the new variety

Table 18. Farmers' ranking of grain traits of improved varieties compared to the local variety, 1993.

Trait	Okashana 1		SDMV 92040 (Kangara)	
Grain size	better	90	better	70
	same	10	same	30
	worse	0	worse	0
Grain color	better	20	better	80
	same	30	same	20
	worse	50	worse	0
Dehulling quality	better	100	better	100
	same	0	same	0
	worse	0	worse	0
Grinding quality	better	0	better	100
	same	0	same	0
	worse	100	worse	0
Food preparation	better	100	better	100
	same	0	same	0
	worse	0	worse	0
Taste	better	20	better	0
	same	40	same	100
	worse	40	worse	0

Source: Ipinge et al. 1996, page 40

into the hands of farmers. The costs of research and extension programs associated with the introduction of Okashana 1 have been estimated on the basis of an approximate allocation of the total national research and extension budget to pearl millet variety development work. The national crops research budget was first divided by the number of crop scientists in government service in order to obtain a rough estimate of the total budget (operations costs plus capital and staffing costs) per scientist. This annual per-scientist cost was then multiplied by the number of scientists involved in pearl millet research each year. This includes both pearl millet breeders and agronomists. The number of scientists is summarized in Table 19.

Prior to Namibia's Independence in 1990, no pearl millet research was carried out by the government of Southwest Africa. However, as described earlier, the Rossing Foundation hired a project manager in 1986, to establish its Okashana Research and Training Centre. Pearl millet variety trials were implemented as a small component of this manager's early workplans (Table 19); most of his time was spent setting up the Centre. Once the Centre was established, a growing portion of time was spent on pearl millet variety testing. After Independence, this pearl millet research program shifted into government hands. The Rossing Foundation maintained a few pearl millet variety trials for another season, but these efforts quickly dissipated.

Table 19. Number of pearl millet scientists in the Namibian research service, 1986-97.

Season	Institute	Breeding/variety selection program (scientist years)	Agronomy program (scientist years)
1986/87	Rossing Foundation	0.1	0
1987/88	Rossing Foundation	0.3	0
1988/89	Rossing Foundation	0.5	0
1989/90	Rossing Foundation	0.5	0
1990/91	Department of Research	0.6	0
1991/92	Department of Research	1.6	0
1992/93	Department of Research	1.5	0.5
1993/94	Department of Research	1.4	0.5
1994/95	Department of Research	1.4	0.5
1995/96	Department of Research	1.4	0.5
1996/97	Department of Research	1.4	0.5
1997/98	Department of Research	1.4	0.2

Namibia's variety development efforts were extended in 1991 with the employment of S Ipinge as a pearl millet breeder, and in 1992 with the hiring of S Niitembu as a cereals agronomist. Niitembu allocated 50% of her time to pearl millet agronomy prior to her departure from the national research service in 1998. Though this is not strictly part of the breeding program, this cost is considered because much of Niitembu's early work involved on-farm variety trials.

In 1991, ICRISAT seconded farm management specialist C M Matanyaire to assist the Namibian research service with station development activities. However, a significant portion of his time was also spent setting up on-farm variety and crop management trials for pearl millet. He left ICRISAT service in 1995.

For the rate of return analysis, the entire costs of the pearl millet research budget were allocated to the development and testing of Okashana 1 up to 1991, the year after its release. For the period 1991 to 1997, 50% of the costs of the national program were allocated. This figure was based on an estimate of the investment costs associated with continuing on-farm variety and management trials, as well as the unrecovered costs of seed multiplication.

Most of the costs of Okashana 1 seed production were initially borne by the national research program. These costs are, in effect, already included in each year's research budget. Most of the proceeds from Okashana 1 seed sales made by the Rossing Foundation were incorporated back into the pearl millet research program, and paid a portion of the seed production costs. However, Okashana 1 seed sale receipts to the government research service were consistently returned to the national treasury. In effect, the research service paid the full operational costs of seed production out of its research budget. Only when the revolving fund was fully established in 1994 were seed sales revenues allocated back to offset the costs of seed production.

In addition, account must be taken of the capital investments made to establish the seed processing and storage facility at the Mahanene Research Station. These amount to about N$ 1.1 million, including the value of the revolving fund for seed purchases. These costs were depreciated over a 10-year period. No additional capital costs were considered.

In addition to the direct Namibian research costs, the analysis must also consider the costs of support provided by ICRISAT This includes support from ICRISAT's pearl millet breeders based in the regional program in Zimbabwe as well as the costs of support provided by ICRISAT breeders in India. The rate of return analysis correspondingly accounts for an investment of 20% of a SMIP breeder's time each

Table 20. Special development projects incorporating a component of pearl millet variety testing and promotion, 1990-98.

Project	Years of operation	Activities related to pearl millet
Northern Namibia Rural Development Program	1996-98	Crop management trials
DANIDA Church Aid	1992-98	Variety and crop management demonstration trials
Rural Development Support Programme	1995-98	Variety and crop management trials
Oxfam Canada	1991-98	Variety and crop management demonstration trials

year since 1986. In addition, one ICRISAT pearl millet physiologist based in India took six months of sabbatical leave to work with the Namibian national program during the 1991/92 season. The full costs of this appointment were considered. The analysis does not consider the costs of ICRISAT's earlier breeding efforts leading to the development of ICMV 88908.

The costs of ICRISAT's involvement in the supply of breeder seed are estimated at US$ 3 kg^{-1}, and the costs of ICRISAT's drought relief production of Okashana 1 during winter 1992 at US$ 1.50 kg^{-1}.

The analysis must also take account of the costs of extension involvement in promoting the adoption of new pearl millet varieties. From 1990/91 (the first cropping season after Independence) until the 1997/98 sowing season, virtually all Okashana 1 seed sales were made through the offices of extension agents. The extension services also helped implement on-farm trials and implemented annual demonstration trials for pearl millet varieties and crop management practices. To account for these costs, the rate of return analysis has incorporated 10% of the total costs of national extension programs in northern Namibia. These data were derived from Anandajayasekeram et al. (1995).

Finally, a range of special agricultural development projects in northern Namibia include, as a limited component, pearl millet variety testing and promotion (Table 20). Most of these programs include testing of alternative pearl millet crop management practices, or support for the improvement of pearl millet processing or marketing. The direct contribution of these programs to the dissemination and adoption of Okashana 1 has been limited. Correspondingly, the costs of these special development projects have not been considered in the rate of return analysis. As a result, the costs of pearl millet dissemination may be marginally underestimated.

Rate of return analysis

An *ex post* analysis was conducted of the returns to investments in the development and dissemination of Okashana 1. This analysis considers research and extension investments from the point of the initiation of pearl millet variety selection in Namibia in 1986 through to the release of Kangara and Okashana 2 in 1998.

The analysis uses an economic surplus approach to estimate the returns to research and extension investments. This method considers the economic gains derived from an increase in pearl millet productivity corresponding with a downward shift in the pearl millet supply function. The productivity gains translate into benefits to producers, in terms of lower production costs; and benefits to consumers associated with the availability of grain products at a lower price than would be the case if the new varieties had not been developed. These gains to producers and consumers represent an economic surplus to the national economy.

The research and extension costs underlying this analysis are outlined above. The analysis assumes an average annual rate of inflation of 10%, the same rate as observed over the 7-year period since Independence. The price of pearl millet grain used in the analysis is N$ 1.10 kg^{-1}, equivalent to about US$ 217 t^{-1}. This represents a conservative estimate of the average costs of a 50-kg bag in early 1998 (consumers buying smaller quantities will pay more per kilogram). Maize grain is marginally cheaper than this price of N$ 1.10 kg^{-1}.

Investment returns were calculated for three scenarios. The baseline scenario uses adoption rates derived from seed sales and farm surveys. This assumes that (i) all seed purchased each year was sown, (ii) farmers saved enough Okashana 1 seed from the previous harvest to sow 75% of the earlier year's Okashana 1 area. This scenario is viewed to be the most realistic.

The value of early variety release and seed multiplication are evident in two alternative scenarios, under which adoption rates—and therefore rates of return—are lower. The second scenario assumes that farmers sowed seed freshly purchased each year, without resowing any of the Okashana 1 seed retained from a previous harvest. Under the third scenario, the initiation of seed multiplication has been delayed by 3 years. Otherwise, the rate of multiplication and adoption follows the same course as scenario 2.

The average annual yield increase derived from Okashana 1 and the two newer varieties was calculated from the trial results summarized in Table 12. Given the low rates of fertilizer adoption despite massive price subsidies, it is assumed that no fertilizer is used. The cost of adopting the new varieties is simply the cost of seed purchase.

The internal rate of return (IRR) was thus calculated. The net present value (NPV) of research investments was also calculated, assuming a discount rate of 5% and 10%.

The results of this analysis reveal the gains obtained from a low-cost breeding program that quickly identified and disseminated a new set of pearl millet varieties. The government of Namibia, in combination with 1CR1SAT, received a 50% internal rate of return on their US $ 3 million investment in the Namibian pearl millet improvement program. The net present value of this return was more than US $ 11 million in 1998 (Table 21).

Rates of return are considerably lower under scenarios 2 and 3. Under scenario 2 (no resowing of farm-saved seed, slowing the speed of Okashana 1 adoption by 50%), the internal rate of return declines to 38%, while the net present value of the investment drops by half, to US$ 5.9 million. Viewed alternatively, doubling the variety adoption rate can improve the rate of return by 30%. Such gains justify larger investments in seed multiplication and dissemination.

Under scenario 3 (no resowing of farm-saved seed, and seed multiplication delayed by 3 years), the *ex post* rate of return declines to 18%. Such results, though approximate and somewhat speculative, highlight the value of the early release of

Table 21. Ex *post* rates of return to pearl millet variety development and dissemination in Namibia.

Adoption scenario[1]	IRR[2]	NPV(10%)[3]	NPV(5%)
Base scenario (49% adoption by 1998)	50%	US$ 11.7 m	US$ 19.4 m
Delayed release and adoption, scenarios 2 and 3			
Scenario 2 - delayed adoption (27% adoption by 1998)	38%	US$ 5.9 m	US$ 10.2 m
Scenario 3 - delayed seed multiplication and adoption (10% adoption by 1998)	18%	US$ 1.0 m	US$2.4 m

1. Adoption rates calculated for each scenario based on the following assumptions. Base scenario: area sown with purchased seed (seed sales data), plus 75% of previous season's Okashana 1 area sown with farm-saved seed. *Scenario 2:* area sown with purchased seed only. *Scenario* 3: area sown with purchased seed only; also assumes initiation of seed multiplication is delayed by 3 years.
2. internal Rate of Return
3. Net Present Value, with discount rate shown in parentheses

new varieties and timely investments in seed multiplication and distribution. Many new varieties are not released quickly; on-farm trials may continue for another 1-2 years in the expectation that trial data will provide a firmer justification for release. And in many cases, seed multiplication begins only 2-5 years after a new variety is released. Such delays can be costly, reducing the potential growth of the agricultural economy.

These returns are high relative to the returns to agricultural research investments elsewhere in Africa. For example, SACCAR (Chisi et al. 1997) recently estimated the returns to sorghum breeding in Zambia to be between 10% and 30%, depending on assumptions made about varietal adoption and demand parameters. ICRISAT's initial estimates show that sorghum and pearl millet breeding research in Zimbabwe yielded an internal rate of return of 25-30%. In comparison, Sanders et al. (1994) cite returns up to 70% for SAFGRAD-supported sorghum breeding programs in West Africa. These programs also made use of germplasm developed by ICRISAT, and promoted rapid dissemination of seed.

Finally, it should be noted that these economic returns only partially account for the range of benefits resulting from new, early-maturing varieties. The yield gains measured in experimental trials probably underestimate the benefit farmers obtain from a crop that can be sown late. When traditional varieties are likely to fail, the early-maturing varieties are likely to offer at least a minimum grain harvest, contributing directly to improved nutrition for farm households in food-insecure areas.

Further, the research investments that led to the development of Okashana 1 have also laid the foundation for a national pearl millet improvement program which did not previously exist. This program has already identified two new varieties improving on the qualities of Okashana 1, using local germplasm as well as genetic material from the international research community. In effect, the investments in the development of Okashana 1 also were investments in building a national breeding program.

The public investments in the multiplication and dissemination of Okashana 1 will also support the distribution of future pearl millet varieties. The newly established seed cooperative is already multiplying Kangara and Okashana 2—and remarkably, multiplication began within months of their release. Thus, past investments in the development of Okashana 1 will also speed the adoption of new varieties.

Conclusions and lessons for the future

The experience of Namibia has highlighted three major factors contributing to the success of a national breeding program:

- Strong assistance from an international research center such as ICRISAT
- Close collaboration with the ultimate clientele of the national research program—the farmer
- Complementary investments in seed production.

All three pearl millet varieties released in Namibia to date were developed by ICRISAT and selected from national variety trials for their suitability to local conditions. Okashana I was essentially developed through ICRISAT's breeding programs in India. The two newer varieties, Kangara and Okashana 2, were developed by ICRISAT in Zimbabwe. Each of these varieties contains germplasm from other parts of Africa and Asia.

Though the international and regional breeding efforts were crucial, the identification of varieties suited to the needs of Namibian farmers was essentially a product of the efforts of Namibia-based breeders and agronomists. In practice, the efforts of international, regional, and national breeders complemented one another, and this greatly accelerated the introduction and selection of new varieties suited to Namibian conditions. The strength of this collaboration serves as a model for pearl millet breeding programs in other parts of the world.

The third partner in this collaboration (in addition to ICRISAT and the Namibian research program) was the small-scale farmer. Farmers were involved from the earliest stages of variety selection in Namibia in 1986/87, and farmers' preferences were the primary factor behind the rapid selection and release of Okashana 1. These farmers immediately perceived the value of early maturity in their cropping system. They could readily see the advantages of higher grain yield when the season was short, and of the larger grain. The strength of this preference hastened the release and dissemination of this variety by several years, and this increased the rate of return to the research investment.

The overall rate of return thus depends not only on returns to investments in breeding, but also the returns to complementary investments in seed production and dissemination. The Chief Crops Research Officer took the initiative to invest a large share of his own time and effort in both producing seed and developing seed production capability in the form of a farmers' cooperative. Without these efforts, it is unlikely that Okashana 1 would have reached even a small proportion of the farmers currently growing the crop. The returns to the pearl millet breeding program may even have been negative.

The prospects for obtaining further productivity gains from pearl millet breeding in Namibia remain uncertain. It may still be possible to obtain moderate yield gains by improving late-maturing landraces. The national breeding program is currently aiming to improve the best available landraces through selection pressure simply targeting yield gains. Further gains might be possible through the introduction of exotic medium-duration germplasm.

In addition, productivity could be increased by developing pearl millet hybrids. Recent experiments with topcross hybrids suggest the possibility of obtaining yields up to 40% higher than Okashana 1, on the experiment station. However, these hybrids still need to be tested under farmers' field conditions.

Larger on-farm productivity gains will require improvements in crop management. That significant gains are possible is evidenced by the large yield differences between experiment station and many on-farm trials, and the average yields farmers obtain in their own fields. However, it is uncertain whether farmers will invest in improved management practices. Most small-scale farmers have chosen to avoid inorganic fertilizer despite an 80% price subsidy. Low and variable returns to labor encourage migration from the farm. It is possible that Namibia, with its harsh agroecology, simply does not have a long-term comparative advantage in cereal grain production.

Questions also remain about the capacity of the grain market to absorb additional production. The cost of maize imports sets a ceiling on grain prices in northern Namibia. This creates the awkward situation where larger farmers with a pearl millet surplus complain about a lack of demand, while grain imports continue. In effect, these farmers perceive a lack of demand at the prices they bargain for. There is undoubtedly a premium market for pearl millet meal at prices 10-20% above the price of maize flour. However, the size of this market appears small.

In sum, high returns to past investments in pearl millet breeding, variety selection, and seed production do not necessarily indicate the likely level of returns to future investments. Nonetheless, past research successes offer a foundation for future gains. If Namibia's research service further exploits the global supply of pearl millet germplasm, continues to promote the rapid dissemination of new varieties, and offers complementary improvements in crop management, the prospects for positive returns will remain favorable.

References

Anandajayasekeram, P., Martella, D.R., Sanders, J., and Kupfuma, B. 1995. Report on the impact assessment of the SADC/ICRISAT Sorghum and Millet Improvement Program. Gaborone, Botswana: Southern African Centre for Cooperation in Agriculture and Natural Resources Research and Training.

Appa Rao, S., Monyo, E.S., House, L.R., Mengesha, M.H., and **Negumbo, I.** 1991. Germplasm collection mission to Namibia. Genetic Resources Progress Report 67. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

Chisi, M., Anandajayasekeram, P., Martella, D., Ahmed, M., and Mwape, M. 1997. Impact assessment of sorghum research in Zambia. Gaborone, Botswana: Southern African Centre for Cooperation in Agriculture and Natural Resources Research and Training.

Friis-Hansen, E. and Rohrbach, D-D, 1993. SADC/ICRISAT 1992 drought relief emergency production of sorghum and pearl millet seed: impact assessment. ICRISAT Southern and Eastern Africa Region Working Paper 93/01. PO Box 776, Bulawayo, Zimbabwe: SADC/ICRISAT Sorghum and Millet Improvement Program.

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). 1994. Annual report: southern and eastern Africa region. PO Box 776, Bulawayo, Zimbabwe: ICRISAT.

Ipinge, S.A. 1997. A proposal for release of pearl millet varieties SDMV 93032 (Kakunya) and SDMV 92040 (Kangara). Report submitted to the Ministry of Agriculture, Water and Rural Development, Government of Namibia. (Limited distribution.)

Ipinge, S.A., Lechner, W.R., and Monyo, E.S. 1996. Farmer participation in on-station evaluation of plant and grain traits: the case of pearl millet in Namibia. Pages 35-42 *in* Drought-tolerant crops for southern Africa: proceedings of the SADC/ICRISAT Regional Sorghum and Pearl Millet Workshop, 25-29 Jul 1994, Gaborone, Botswana (Leuschner, K. and Manthe, C.S., eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

Karanga, D.D. 1990. The rate of return to maize research in Kenya, 1955-88. MSc thesis, Department of Agricultural Economics, Michigan State University, East Lansing, Michigan, USA.

Keyler, S. 1995. Economics of the pearl millet subsector in northern Namibia: a summary of baseline data. ICRISAT Southern and Eastern Africa Region Working Paper 95/03. PO Box 776, Bulawayo, Zimbabwe: SADC/ICRISAT Sorghum and Millet Improvement Program.

Lechner, W.R. 1996. Pilot project for small-scale pearl millet seed production in Namibia. Pages 275-277 *in* Drought-tolerant crops for southern Africa: proceedings of the SADC/ICRISAT Regional Sorghum and Pearl Millet Workshop, 25-29 Jul 1994, Gaborone, Botswana (Leuschner, K. and Manthe, CS., eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

Lechner, W.R. 1997. Seed multiplication and distribution through a farmers' cooperative in Namibia. Pages 135-138 *in* Alternative strategies for smallholder seed supply: proceedings of an International Conference on Options for Strengthening National and Regional Seed Systems in Africa and West Asia, 10-14 Mar 1997, Harare, Zimbabwe (Rohrbach, D.D., Bishaw, Z., and van Gastel, A.J.G., eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

Matanyaire, C M . 1995. On-farm testing of improved pearl millet varieties. Chapter 6, pages 1-5 *in* Progress Report 1994/1995, Division of Plant Production Research, Directorate of Agricultural Research and Training. Windhoek, Namibia: Ministry of Agriculture, Water and Rural Development. (Limited distribution.)

Matanyaire, C.M. 1996a. Farmers' production practices and perceptions of problems as a guide for research on rainfed food crops in northern Namibia. Development Southern Africa 13(5):681-691.

Matanyaire, C.M. 1996b. Pearl millet production systems in the communal areas of northern Namibia: priority research foci arising from a diagnostic survey. Pages 43-58 *in* Drought-tolerant crops for southern Africa: proceedings of the SADC/ICRISAT Regional Sorghum and Pearl Millet Workshop, 25-29 Jul 1994, Gaborone, Botswana (Leuschner, K. and Manthe, C.S., eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

Matanyaire, C M . and Gupta, S.C. 1996. On-farm evaluation of improved pearl millet varieties in Namibia. Pages 59-63 *in* Drought-tolerant crops for southern Africa: proceedings of the SADC/ICRISAT Regional Sorghum and Pearl Millet Workshop, 25-29 Jul 1994, Gaborone, Botswana (Leuschner, K. and Manthe, C.S., eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

Matanyaire, C.M. and Niitembu, S. 1996. On-farm testing of improved pearl millet varieties. Pages 1.11-1.13 *in* Progress Report 1995/96, Division of Plant Production Research, Directorate of Agricultural Research and Training. Windhoek, Namibia: Ministry of Agriculture, Water and Rural Development. (Limited distribution.)

Matanyaire, C.M. and Niitembu, S. Unpublished. On-station pearl millet phosphorus and nitrogen response, 1994/95. Report submitted to the Division of Plant Production Research, Directorate of Agricultural Research and Training, Ministry of Agriculture, Water and Rural Development.

Namibia Early Warning and Food Information Unit. 1997. Namibia Early Warning Bulletin, 29 Jan 1997. Windhoek, Namibia: Ministry of Agriculture.

Namibia Early Warning and Food Information Unit. 1998. Personal communication, A. Sheuyange, Feb 1998.

Rai, K.N., Kumar, K. Anand, Andrews, D.J., Rao, A.S., Raj, A.G.B., and Witcombe, J.R. 1990. Registration of ICTP 8203 pearl millet. Crop Science 30(4):959.

Rohrbach, D.D. 1995. Millet production and marketing options for Namibia. Pages 56-68 *in* Proceedings of the Second National Pearl Millet Workshop, 7-8 Nov 1994, Windhoek, Namibia. PO Box 776, Bulawayo, Zimbabwe: SADC/ICRISAT Sorghum and Millet Improvement Program (semi-formal publication).

RDSP (Rural Development Support Programme) 1998. Personal communication, J. Doughty, Feb 1998.

SADC Regional Early Warning Unit. 1997. Food security quarterly bulletin, Jan/Feb 1997. Bulletin No. 4.96. Harare, Zimbabwe: Southern African Development Community.

SADC Regional Early Warning Unit. 1998. Food security quarterly bulletin, Dec 1997/Jan 1998. Bulletin No. 4.97. Harare, Zimbabwe: Southern African Development Community.

Sanders, J., Bezuneh, T., and Schroeder, A.C. 1994. Impact assessment of the SAFGRAD commodity network. Washington, DC, USA: United States Agency for International Development, Africa Bureau.

Witcombe, J.R., Rao, M.N.V.R., and Lechner, W.R. 1995. Registration of ICMV 88908 pearl millet. Crop Science 35:1216-4217.

Acronyms

BMZ	Bundesministerium fur Wirtschaftliche Zusammenarbeit
CIDA	Canadian International Development Agency
DANIDA	Danish International Development Agency
FAO	Food and Agriculture Organization of the United Nations
GTZ	Deutsche Gesellschaft fur Technische Zusammenarbeit
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
INTSORMIL	International Sorghum and Millet Collaborative Research Support Program
IRR	internal rate of return
NPV	net present value
RDSP	Rural Development Support Programme
SACCAR	Southern African Centre for Cooperation in Agriculture and Natural Resources Research and Training
SADC	Southern African Development Community
SAFGRAD	Semi-Arid Food Grain Research and Development
SMIP	Sorghum and Millet Improvement Program
USAID	United States Agency for International Development

Annex 1. Yield of Okashana 1 versus local variety under varying rainfall and crop management conditions, 1992/93 to 1995/96.

The following data need to be interpreted with care. In most cases, the distinction between farmer management and researcher management has not been clearly specified in the associated text. Nor is information provided on rainfall and sowing date. The name of the local variety is generally not provided, and it is unclear whether the same local variety was tested at different sites. As a result, these data simply provide a rough comparison between Okashana 1 and a generic traditional variety. The yields are highly variable and probably depend heavily on sowing date in relation to rainfall distribution, and on the quality of trial management.

Table A1. Mean grain yield (t ha^{-1}) averaged over 1-4 researcher-managed, farmer-implemented on-farm variety trials in each of four regions, 1992/93 season.

	Ovambo West	Ovambo East	Kavango West	Kavango East
Okashana 1	1.71	1.83	1.93	1.25
Local variety	1.05	1.33	2.00	1.33

Source: Matanyaire and Gupta 1996

Table A2. Mean grain yield (t ha^{-1}) from survey data, cm-farm trials, and experiment station trials in northern Namibia, 1992/93 season.

	Survey data	Researcher-managed on-farm trials	Mahanene research station trials
Okashana 1	0.20	1.65	3.87
Local variety	0.15	1.14	3.63

Source: Matanyaire 1996b

Table A3. Mean grain yield (t ha^{-1}) from researcher-managed, farmer-implemented on-farm variety trials at two locations in northern Namibia, 1993/94 season.

	Ovamboland	Kavango	Mean
Number of locations	6	8	
Okashana 1	1.00	0.73	0.85
Local variety	0.76	0.80	0.78

Source: Matanyaire and Gupta 1996

Table A4. Mean grain yield (t ha^{-1}) from farmer-managed, farmer-implemented on-farm variety trials at two locations in northern Namibia, 1993/94 season.

	Ovamboland	Kavango	Mean
Number of locations	2	3	
Okashana 1	0.72	0.32	0.49
Local variety	0.67	0.36	0.49

Source: Matanyaire and Gupta 1996

Table A5. Mean grain yield (t ha^{-1}) from researcher-managed, farmer-implemented on-farm variety trials at two locations in northern Namibia, 1993/94 season.

	Ovambo West	Ovambo East	Kavango West	Kavango East
Okashana 1				
Without fertilizer	1.02	0.45	1.00	0.24
With fertilizer (15 kg P, 40 kg N ha^{-1})	1.29	0.59	1.12	0.34
Local variety				
Without fertilizer	0.73	0.45	0.85	0.31
With fertilizer (15 kg P, 40 kg N ha^{-1})	0.72	0.64	1.40	0.49

Source: ICRISAT 1994, pages 62-63

Table A6. Grain yield from farmer-managed, farmer-implemented on-farm variety trials, mean of two locations, Northcentral region, 1994/95 season.

	Grain yield (t ha^{-1})
Okashana 1	0.42
Local variety	0.36

Source: Matanyaire 1995

Table A7. Mean grain yield (t ha^{-1}) from farmer-managed, farmer-implemented on-farm fertility management trials, averaged across an unknown number of locations, Northcentral region, 1994/95 season.

	No fertilizer	15 kg P ha^{-1}	20 kg N ha^{-1}	15 kg P + 20 kg N ha^{-1}
Okashana 1	0.45	0.58	0.73	0.82
Local variety	0.28	0.45	0.61	0.55

Source: Matanyaire 1995

Table A8. Mean grain yield (t ha^{-1}) in on-station fertility management trials at Mashare and Mahanene, 1994/95 season.

	No fertilizer	10 kg P, 15 kg N ha^{-1}	15 kg P, 20 kg N ha^{-1}	15 kg P, 30 kg N ha^{-1}
Mashare				
Okashana 1	2.89	2.58	2.33	2.18
Local variety	1.48	1.36	1.35	1.26
Mahanene				
Okashana 1	0.57	0.94	2.04	1.12
Local variety	0.61	1.53	0.99	2.57

Source: Matanyaire and Niitembu unpublished

Table A9. Mean grain yield (t ha^{-1}) in farmer-managed, farmer-implemented trials, 1995/96 season.

	Omusati	Oshana, Ohangwena, and Oshikoto	Kavango	Caprivi
Okashana 1	1.54	0.92	1.01	1.83
Local variety	0.77	0.79	0.78	1.62

Source: Matanyaire and Niitembu 1996

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The semi-arid tropics (SAT) encompasses parts of 48 developing countries including most of India, parts of southeast Asia, a swathe across sub-Saharan Africa, much of southern and eastern Africa, and parts of Latin America. Many of these countries are among the poorest in the world. Approximately one-sixth of the world's population lives in the SAT, which is typified by unpredictable weather, limited and erratic rainfall, and nutrient-poor soils.

ICRISAT's mandate crops are sorghum, pearl millet, finger millet, chickpea, pigeonpea, and groundnut; these six crops are vital to life for the ever-increasing populations of the semi-arid tropics. ICRISAT's mission is to conduct research which can lead to enhanced sustainable production of these crops and to improved management of the limited natural resources of the SAT. ICRISAT communicates information on technologies as they are developed through workshops, networks, training, library services, and publishing.

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