

Cooperation-88: A High Yielding, Multi-Purpose, Late Blight Resistant Cultivar Growing in Southwest China

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Abstract Cooperation-88 (C88) is a high yielding potato cultivar with durable resistance to *Phytophthora infestans* Mont. de Bary and excellent virus resistance. This has permitted the cultivar to rapidly increase its production area in Yunnan Province of China, as well as in neighboring provinces and countries. C88 is the result of a cross between I-1085, a clone from India selected for late blight (LB) resistance in Mexico and distributed by the International Potato Center (CIP), and a bulk pollen of a poorly

adapted but highly LB resistant population with its origin in *Solanum andigena* from CIP Peru. C88 has excellent vegetative growth; it is late maturing under the long day summer growing season in Yunnan Province. It is much earlier maturing under the low elevation and warmer winter season of Yunnan. Experimental yields ranged from 23 to 55 t/ha, out-yielding the control cultivar Mira by 5% to 76%. Tuber quality is excellent, garnering a premium price in the markets. C88 has also become the preferred cultivar for the chipping potato industry, which uses medium-sized tubers, while the larger ones go for the fresh table market. Current estimates place the total area under production at 390,000 ha in Yunnan and its neighboring provinces, making C88 one of the most widely grown cultivars in the world today, less than 15 years after release.

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Resumen Cooperation-88 (C88) es una variedad de papa de alto rendimiento con resistencia durable a *Phytophthora infestans* Mont. de Bary y de excelente resistencia a virus. Esto le ha permitido un rápido incremento en el área de producción en la Provincia de Yunnan en China, así como también en provincias y países vecinos. C88 es el resultado de una cruce entre I-1085, un clon de la India seleccionado para resistencia al tizón tardío (TT) en México y distribuido por el Centro Internacional de la Papa (CIP), y polen masivo de una población de pobre adaptación, pero altamente resistente al TT, con su origen en *Solanum andigena* del CIP, en Perú. C88 tiene un excelente crecimiento vegetativo; es tardía bajo el ciclo de cultivo de día largo del verano en la Provincia de Yunnan. Es de madurez mucho más temprana en elevaciones bajas y en la estación de inviernos cálidos de Yunnan. Los rendimientos experimentales variaron de 23 a 55 t/ha, superando a la variedad testigo Mira por 5% a 76%. La calidad del tubérculo es excelente, mereciendo precios preferenciales

en los mercados. C88 también se ha convertido en la variedad preferida para la industria del freído de la papa, que utiliza tubérculos de tamaño medio, mientras que los grandes van al mercado fresco. Las estimaciones actuales ubican al área bajo producción en 390,000 ha en Yunnan y en las provincias vecinas, haciendo de C88 una de las variedades más ampliamente sembradas en el mundo hoy, a menos de quince años de su liberación.

Keywords Yunnan · Potato chips · Wide adaptation · Culinary quality

Introduction

Potatoes are a major food crop in Southwest (SW) China, which includes over 40% of the total potato area in China (Jansky et al. 2009). Potatoes are grown year round in this area, but primarily as a summer crop from April to September in the highlands (over 2,000 m above sea level). At lower elevations, the potato is grown as an autumn crop (July to December), a winter crop (October to March), or an early-spring crop (December to May). Late blight caused by *P. infestans* is the single most important production constraint, particularly during the wet summer months (Song and Wang 1993).

The cultivar Mira, which originated from Germany, had been the dominant cultivar since the 1960s, occupying about 80% of the total potato production area in SW China until the mid-1990s (Wang et al. 1989). Although this cultivar has very good adaptation to this area and is mainly grown in the highlands, its productivity has declined due to virus infection and susceptibility to the changing population of *P. infestans*. Substantial improvement in potato productivity would be attained by identifying cultivars with excellent resistance to viruses and *P. infestans*, and by having an adequate basic seed-tuber production program in the sub-tropical highland areas of Yunnan.

In 1986, the International Potato Center (CIP) and the Yunnan Normal University (YNU) identified a common goal: to select superior clones for late blight resistance, eating quality, and virus resistance, along with initiating a tissue-culture-based basic seed production program. This would rapidly multiply promising clones for distribution and further multiply advanced clones or newly released cultivars. Thus, a number of cultivars and advanced clones were introduced from CIP and evaluated under the local conditions. Four cultivars (or clones), namely I-1085 (Sita), CIP-24 (B71.240.2, also known as Achirana Inta), CIP 378711.7 and CFK69.1, were selected from the CIP germplasm, due to their high level of resistance to *P. infestans* and yields above the check cultivar Mira (Wang et al. 1989). These clones were desirable as parental lines in

the researchers' efforts to develop superior adapted clones with *P. infestans* resistance.

Strategy

Late blight resistance is the key production constraint in all of the sub-tropical highlands. Generally, the material with late blight resistance has been poorly adapted to the longer day growing conditions in the highlands. A CIP-supported MSc. thesis breeding project was initiated in the Philippine highlands with a Vietnamese graduate student (Chien 1989). The strategy was to choose the better adapted late blight resistant CIP clones as the female parents and then utilize the CIP germplasm that is very late blight resistant but poorly adapted as a source of bulk pollen. The thesis involved two cycles of recurrent selection.

Extra true potato seed (TPS) from this thesis project was provided to the Yunnan project for evaluation. Over 8,000 seeds from 17 crosses were initially evaluated in 1990 at the Agricultural Extension Station in Huize county, which is over 2,200 m above sea level. After nine rounds of selection and trials in 5 years, only a few clones remained, with selection #88 being the most promising one for release (He and Wang 1993). In 1995, #88 passed all multi-locational and provincial trials. In 1996, at a special meeting in YNU, the selection was released as a cultivar for Yunnan Province and named Cooperation-88 in recognition of the collaborative work that resulted in this cultivar.

In 1994, after YNU did meristem culture to eliminate viruses, they entered the cultivar into the basic seed program. The first batch of mini-tubers was produced in 1995. Evidence from all the field observations indicated that C88 was an outstanding clone with strong demand from farmers and consumers, so production of mini-tubers continued.

Description

Pedigree The female parent, I-1085, is a white-skinned, white flesh potato clone with late maturity, high yield and chipping quality (Wang et al. 1989). It is a selection from the India potato program which was sent to Mexico for LB screening. CIP obtained it for distribution and utilization. I-1085 was introduced to YNU in 1986, released in 1991, and gained popularity with growers in Yunnan, soon reaching over 10,000 ha in production. It was also a promising clone in the Philippines.

The male parent is a bulk pollen source from a population of late blight resistant clones selected in the northern highlands of the Philippines in 1986 from late blight resistant germplasm obtained from CIP Lima, Peru.



Fig. 1 C88 field in the summer season in the highlands of Yunnan Province

These clones were considered to be poorly adapted to longer day conditions at 20° to 30° latitude. The pollen was collected from all fertile flowers, mixed, and then used to pollinate.

Foliage The plants are vigorous with an erect growth habit. During the long days of summer, there is an abundance of flowers and berries (Fig. 1). The crop matures in 120–150 days during the long days of summer with up to 13.5 h of daylight, but during the winter season the crop canopy is smaller and matures in 80–120 days with virtually no flowering.

Tubers Tubers are generally large and blocky (Fig. 2). Tuber skin is reddish pink with more pigmentation around the shallow eyes. The flesh colour is a light yellow, similar to Yukon Gold. The tubers are moderately resistant to bruising and to greening in the light. Consumers are paying a substantial premium for C88 as table potatoes, compared to the cultivar Mira.

Late Blight Resistance Since the selection of C88 in 1995, it continues to show a high level of durable resistance to

Table 1 Yield of C88 grown in plots of at least 0.07 ha in fields with the CV Mira (local check) in Huize County, Yunnan province

Year	Yield (t ha ⁻¹) ^a	Yield increase over Mira (%)
1994	54.6	36
1995	51.5	47
1996	40.6	42
1997	40.2	76
1998	34.5	68
1999	34.8	35
2000	30.7	41

^a In 1994 and 1995, the seed tubers for both C88 and Mira were from greenhouse grown stem cuttings from Yunnan Normal University

foliar *P. infestans* infection, and it is highly resistant to tuber infection. Late blight resistance for C88 has been evaluated annually from 2002–2009 under local conditions, where all detectable virulence genes existed naturally every year. The inoculation test with a set of isolates included IPO 428.2 (A2 mating type, 1.2.3.4.5.6.7.8.9.10.11) and X-4 (A1 mating type, 1.2.3.4.5.6.7.8.9.10.11), further confirmed its resistance to *P. infestans* compared with very susceptible cultivar Bintje and susceptible cultivars Atlantic and Mira. For C88, small and restricted lesions were noted with few mycelium. Its durable resistance is attributed to its *S. andigena* background, which carries R1 and R3a genes/analog (Li et al. 2008), which have been cloned and sequenced (Ballvora et al. 2002; Huang et al. 2005). In August, when the summer crop matures, late blight is present and is washed into the soil by the rain. Even when the farmers delay the harvest until December, no tuber infection is noted.

Virus Resistance C88 is highly resistant to PVY^o and PVX, and moderately resistant to PLRV when inoculated in the greenhouse. This permits farmers to keep their seed for many generations. One can observe many fields of C88 before finding a single visually infected virus plant, even though other cultivars are heavily infected with PLRV and PVY.

Fig. 2 Tubers and tuber flesh of C88



Table 2 Increasing popularity of C88 in Yunnan Province

	Year	Total potato area (ha)	Area planted to C88 (ha)	C88% of total	Cultivar rank
	1997	249,300	2,666	1.07	6
	2000	316,900	40,000	12.62	3
	2002	348,000	76,867	22.09	3
	2004	448,000	98,400	21.96	2
	2006	539,900	133,333	24.69	2
Data provided by County Agricultural Technology Extension Stations	2008	618,000	156,333	25.30	2
	2009	634,100	186,667	29.44	1

Nematode and Scab Resistance Under Field Conditions C88 is moderately resistant to *Globodera pallida* race 1 and 2. It has low resistance to *G. rostochiensis* race 1. Resistance to common scab (*Streptomyces scabies*) is medium, similar to the cv. Atlantic.

Agronomic Performance C88 performed well in all the comparative farm trials conducted (Table 1). In Huize, where C88 was initially selected, it produced excellent yields of over 50 t/ha using the seed tubers from greenhouse grown stem cuttings in 1994 and 1995 (Table 1). In subsequent trials, farmer-harvested and stored tubers were retained for seed. Although yield did decline, it remained above 30 t/ha, averaged over a large number of on-farm trials (Table 1). The decline in yield is primarily due to the physiological ageing of farmers' seed, which is generally stored under sub-optimal conditions. The possibility of virus infection, however, particularly due to PLRV,

could also be a contributing factor to the observed yield decline.

In Xundian County (2400 m. asl), the C88 started from clean seed in 1996. Many farm trials were done with C88, averaging over 35.4 t/ha and yielding 37 to 68% more than Mira. These farm trials clearly reflect why C88 has rapidly gained its popularity in Yunnan province (Table 2). It is now ranked as the most widely grown cultivar in the Province. At first, the summer crop was the most popular season; however, C88 is now preferred during the short day winter season as well, yielding over 30 t/ha in 80 to 90 days. The lower elevation farmers obtain C88 seed from highland summer crop growers.

Utilization

The predominant use of C88 is for fresh consumption. Farmers get a premium price because consumers prefer the appearance and taste of C88. It can be compared to Yukon Gold for shape, flesh colour, cooking consistency and taste. C88 is also sold for table potatoes to neighboring countries, especially Vietnam during its rainy season from July to November.

Furthermore, C88 is now the preferred cultivar for the potato chip industry in Yunnan. Attempts to grow the cultivar Atlantic failed due to late blight presence and poor seed quality. C88 can be utilized throughout the year for



Fig. 3 C88 chips from a winter crop fresh harvest and a summer crop delayed harvest

Table 3 Area planted to C88 and its average yield in neighboring provinces in 2009

Province	Area (ha)	Yield (t ha ⁻¹)
Guangxi	30,000	33.5
Guizhou	96,670	32.0
Sichuan	60,000	33.7
Chongqing	16,670	22.5

Data provided by the County Agricultural Technology Extension Stations of Guangxi and Guizhou provinces, Xichang Agricultural Science Research Institute in Sichuan province, and the Potato Hi-tech Research Institute in Chongqing province

producing potato chips. Freshly harvested potatoes are available from February to September. For the October to January period, the farmers agree to delay harvesting the potatoes destined for chips until they are needed. In early February, they transition from delayed harvest potatoes to fresh harvest (Fig. 3). For the delayed harvest, the crop stays in the ground until December, when soil temperatures can drop to 6°C. The crop is harvested by late December and stored for up to 1 month at the warehouses of middlemen or at the processing factory. The chip plants only utilize the medium-sized tubers. The larger tubers are utilized for the fresh market, and the small ones are often kept for seed.

Production Trends and Spread of C88

The area under production with C88 has also spread to the neighboring provinces of Guizhou (96,670 ha), Sichuan (60,000 ha), Guangxi (30,000 ha) and Chongqing (16,670 ha), totaling 203,340 ha in 2009, which surpasses that of Yunnan (Table 3). Seed of C88 is now also spreading to Vietnam and Myanmar. The rapid spread of C88 is mainly attributed to its high yield, good culinary and chip quality, as well as for its high resistance to viruses and late blight. These factors have promoted its rapid adoption in the sub-tropical highlands because farmers can retain the seed with good health by themselves for more than one decade.

In comparison to C88's production area of 390,000 ha, the leading cultivar in the USA and Canada, Russet Burbank, occupies about 175,000 ha. In India, Kufri Jyoti and Kufri Bahar are the two leading cultivars, with 650,000 and 480,000 ha respectively (Mohinder Kadian personal communication). There are also several cultivars that cover a larger area in the northern part of China.

Clones from the same MSc. Thesis (Chien 1989) are now also the major cultivars grown in the Philippines highlands, as well as in the southern highlands of Vietnam, especially the clone initially named LBR 1–5 (Chien 1989), and later named PO-3 in Vietnam and Igorota in the Philippines. As C88 continues to increase in importance, the huge success of this thesis project—particularly as it has

benefited poor highland potato farmers—would be an important socio-economic study.

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