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Production Analysis of Corn (*Zea mays* L.) in Agricultural District VII Valle de Bravo, State of Mexico

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ABSTRACT

Objective: Analyze corn production in Rural Development District (RDD) 7 “Valle de Bravo”, State of Mexico, focusing on the relationship between yield and sown area, as well as identifying factors that may affect this production.

Design/methodology/approach: Data from the Agri-Food and Fisheries Information System (SIAP) on sown area, production, and yield of corn (2003-2021) were used. Additionally, questionnaires were provided to RRD 7 producers. Statistical analyses were carried out with SPSS software and simple linear regression models were applied to evaluate productivity and associated factors.

Results: Corn yield showed linear growth; however, the sown area decreased as farmers have dedicated themselves to producing more profitable crops. Guaranteed prices per ton were deemed inadequate and high input costs hindered agricultural production.

Limitations: Farmers faced challenges such as high production costs and limited access to financial resources. Government programs offer some support for corn production; however, this is insufficient to address the structural problems of the sector.

Conclusions: A comprehensive strategy is needed to address the systemic challenges facing the corn sector. This includes measures to improve productivity, reduce production costs, ensure fair prices, promote crop diversification and enhance access to resources and technologies that guarantee the long-term sustainability of the agri-food sector.

Keywords: Corn, production, yield, government subsidies.

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INTRODUCTION

Corn, an agricultural crop of global importance, stands out for its multiple uses in human and animal food, as well as in industry. Its versatility and nutritional value have made it a highly influential product in international markets (Bada-Carbajal *et al.*, 2021). The United States and China lead global corn production, while Mexico ranks as the

eighth-largest producer worldwide. The historical importance of corn in Mexico is undeniable; as the center of origin of this cereal, its *per capita* consumption is significant, feeding more than 100 million Mexicans. In addition to its cultural relevance, corn plays a crucial role in the industry, serving as a raw material for a wide range of products and by-products (Basilio-Peña *et al.*, 2019).

Despite Mexico's significant corn production, the country faces a challenge in meeting domestic demand. Approximately 41% of national consumption is met through imports from the United States and Brazil (Tadeo Robledo *et al.*, 2015; SIAP, 2019). This dependence on imports has been increasing, highlighting the influence of the expected rural average price on the domestic market (Moreno Sáenz *et al.*, 2016). In 2021, national corn production reached 27,503,477 tons (t), cultivated over an area of 7,309,546 hectares (ha). The states of Sinaloa and Jalisco stood out as the main producers in Mexico, while the State of Mexico ranked third nationally. However, productivity in the State of Mexico remains below other states, with an average yield of 3.96 t ha^{-1} (SIAP, 2022). This productivity disparity results in a significant deficit in corn consumption in the State of Mexico, which is the second-largest corn consumer in the country after Jalisco. This gap between production and consumption is reflected in an unmet demand of 389,310 tons of white corn and 741,740 tons of yellow corn, accounting for 34% and 66% respectively (García Salazar *et al.*, 2016).

The State of Mexico, with its 125 municipalities and 11 regional delegations, plays a crucial role in the primary sector, contributing 5.7% of the country's employment. It is divided into 8 Rural Development Districts (RDD), with RDD 7 "Valle de Bravo" standing out in the state for its corn production, ranking third in 2021 with a total of 153,935.94 tons and an average yield of 3.71 t ha^{-1}. This yield is slightly above the national average but significantly lower than the yields in Sinaloa and Jalisco (SIAP, 2022). The historically low productivity in Mexico, especially in regions such as the central and southeastern parts of the country, is attributed to spatial, temporal, and cultural issues. Additionally, 80% of corn producers in these areas farm under rainfed conditions on small plots, using low-cost and minimally mechanized farming systems (Santillán Fernández *et al.*, 2022).

Therefore, addressing this challenge requires a comprehensive approach that includes improving corn production and yield through the use of improved seeds, fertilizers, and agrochemicals. Technical assistance also plays a crucial role in this process, promoted through legislation, federal subsidy programs, and the creation of institutions such as the Agricultural, Aquaculture, and Forestry Research and Training Institute of the State of Mexico (ICAMEX) (SADER, 2018; Ramírez Jaspeado *et al.*, 2020). In this context, the present article focuses on analyzing corn production in RDD 7 "Valle de Bravo," concentrating on the relationship between yields and the planted area, as well as identifying the factors that may affect such production.

MATERIALS AND METHODS

Study Site

The study was conducted in RDD 7 "Valle de Bravo," composed of 12 municipalities in the State of Mexico (Table 1). The corn grown in this RDD is adapted to high valley areas, with elevations ranging from 2200 to 2600 meters above sea level, a temperate subhumid

Table 1. Geographic Coordinates of the Municipalities of RDD 7 “Valle de Bravo,” State of Mexico.

Municipality	Latitude	Longitude
Amanalco	19.1936 N	100.0753 W
Donato Guerra	19.3506 N	100.2072 W
Ixtapan del Oro	19.1819 N	100.2100 W
Otzoloapan	19.1112 N	100.3054 W
Santo Tomás	19.2834 N	100.2093 W
Valle de Bravo	19.1924 N	100.1330 W
Villa de Allende	19.3573 N	100.1259 W
Vila Victoria	19.4383 N	100.0189 W
Zacazonapan	19.0833 N	100.2667 W
Temascaltepec	19.0378 N	100.0283 W
San Simón de Guerrero	18.9917 N	100.1783 W
Luvianos	18.9765 N	100.3083 W

Note: The coordinates are approximate and correspond to the location of the centers of each municipality according to the data source INEGI, (2022).

climate with an average annual temperature of 15 °C, and annual precipitation ranging from 900 to 1600 mm (INEGI, 2022).

Data Collection

The productivity analysis was conducted using data from SIAP on the variables of planted area (ha), harvested area (t), production volume (t), and yield (t ha^{-1}) from the eight Rural Development Districts that make up the State of Mexico during the period 2003-2021. In addition, a directed sampling was carried out during the first semester of 2021 using questionnaires for corn producers. These questionnaires addressed various aspects, such as the area allocated for corn planting, the destination of the production (self-consumption or sale), the seed varieties used (local or hybrid), field yield (t ha^{-1}), production value (\$ t^{-1}), and production costs (\$ ha^{-1}).

Statistical Analysis

The differences in productivity among the districts were determined through an analysis of variance and a Tukey mean comparison test with a 95% confidence level. To delineate the evolution of corn production in RDD 7 “Valle de Bravo,” simple linear regression models were fitted to the variables of planted area, production volume, and yield. The statistical analyses were performed using IBM SPSS software.

RESULTS AND DISCUSSION

Corn grain yield in RDD 7 “Valle de Bravo” showed a linear growth trend during the period 2003-2021, with a minimum yield recorded in 2006 (2.73 t ha^{-1}) and a maximum in 2016 (4.52 t ha^{-1}). This upward trend in yields was associated with the National Program for the Sustainable Modernization of Traditional Agriculture (MasAgro), which was formalized in the State of Mexico in 2012, promoting the use of improved seeds and fertilizers (CIMMYT-MASAGRO, 2012; Ramírez Jaspeado *et al.*, 2020). However, starting in 2017, the average yield in the State of Mexico decreased to 3.66 t ha^{-1}, while in RDD 7 "Valle de Bravo" the difference was smaller (3.89 t ha^{-1} in the 2013-2017 period and 3.76 t ha^{-1} in 2017-2021). Despite the increase in productivity, yields in the State of Mexico and in RDD 7 "Valle de Bravo" remained lower compared to the main producing states in the country, such as Jalisco (6.76 t ha^{-1}) and Sinaloa (11.32 t ha^{-1}). In contrast to the historical increase in yield, production values showed a slight downward trend over the same period, decreasing from a production of 208,707 t in 2003 to 153,936 t in 2021. However, there were years in the last decade with high production levels, such as in 2016 and 2017 (220,434 t and 202,364 t, respectively). The gradual decrease in production, even considering the increase in yields, may be mainly due to the decline in the linear trend of the planted corn area ($R=0.813$), which decreased from 61,702 ha in 2003 to 41,507 ha in 2023 (Figure 1).

The decrease in the area allocated to corn, among other factors, occurred due to the crop change implemented by farmers in search of higher economic returns.

In the last decade, crops such as forage oats increased from a planted area of 12,344 ha in 2010 to 19,971 ha in 2020. Other examples include vegetables, whose cultivation is of interest to farmers because, although production costs are higher, production values also significantly increased. Another example is the potato crop, which reached 836 ha planted in 2010, while by 2020 this area increased to 1,578 ha. The production value showed an upward trend due to the increase in the price per ton of corn, which rose from $1,424.83 MXN in 2003 to $6,051.30 MXN in 2021 (CEDRSSA, 2019) (Figure 2). However, this increase does not necessarily translate into higher profits for producers, as inflation and the rise in input costs must also be considered.

The productivity of RDD 7 "Valle de Bravo" compared to other districts in the State of Mexico shows statistically similar yields, with the exception of Tejupilco. The RDDs of Atlacomulco and Toluca lead in planted area, harvested area, and production volume, although this is due to a larger cultivated area and concentrated agricultural resources. Meanwhile, the RDDs of Coatepec Harinas and Texcoco have smaller cultivated areas but higher yields, comparable to other RDDs, suggesting greater productivity that can be attributed to favorable edaphoclimatic conditions (Table 2).

The questionnaire results showed that farmers in RDD 7 "Valle de Bravo" plant an average of 2.5 ha per cropping cycle, with 77% using conventional machinery, although a significant percentage still uses manual tillage (17%). Currently, it is possible to request financial subsidies for the acquisition of tractors, motorized machinery, and precision agriculture implements through the Ministry of Agriculture and Rural Development (SADER) and the Ministry of the Field (SECAMPO). However, 86% of the interviewed producers have not received this type of support, due to a lack of financial capital to cover the non-subsidized portion by government institutions. Regarding seed supply, only 26% of farmers obtain seeds through the self-production of native varieties, while 56% of producers do so through two companies: Asgrow Monsanto, with varieties "H50," "Niebla," and "Faisán"; and the Mexican company Aspros with cultivars "722" and

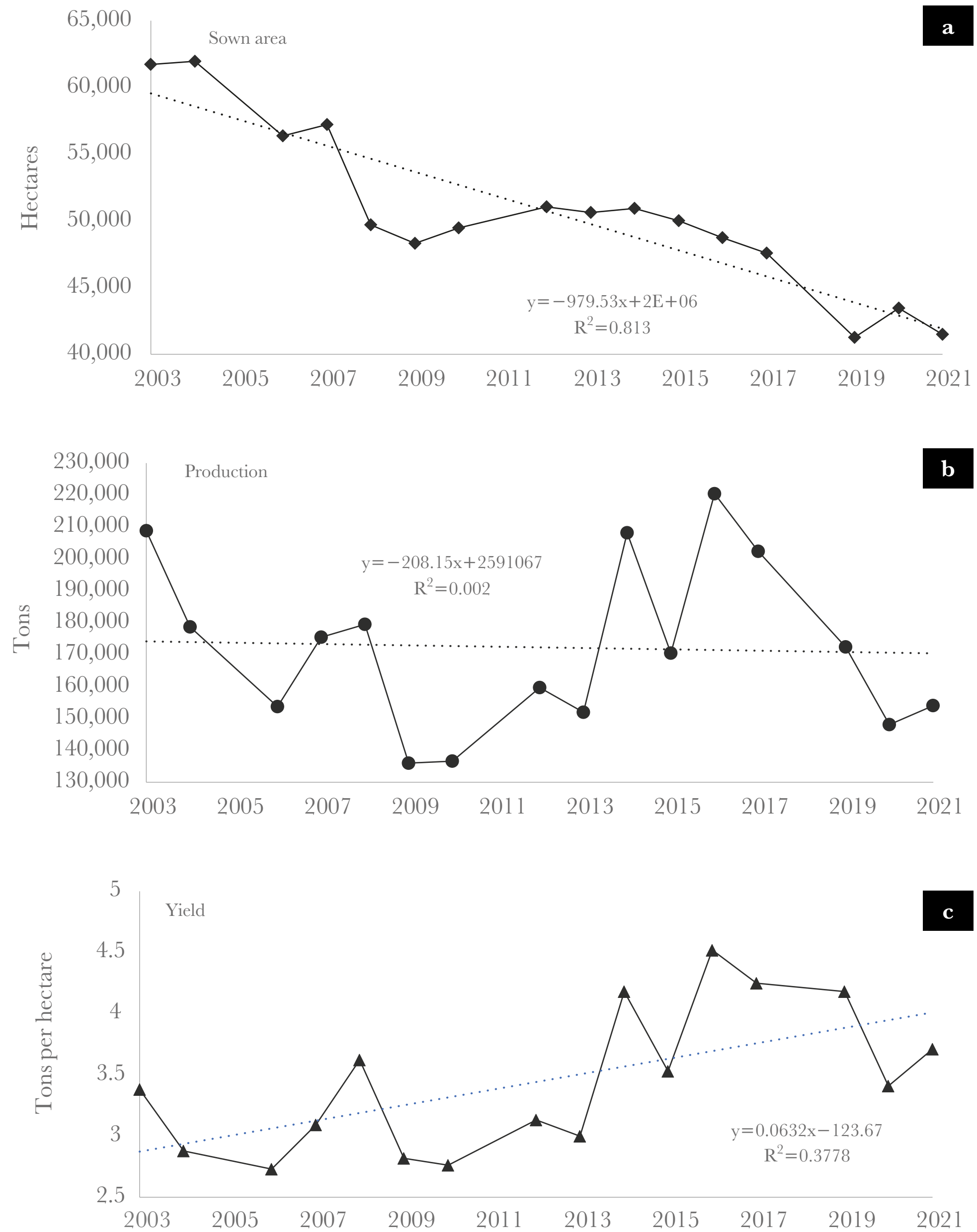

Figure 1. Variation in production values (a), planted area (b), and yield (c) during the period (2003-2021) in RDD 7 "Valle de Bravo," State of Mexico. The graphs show the values for hectares planted (a), total tons harvested (b), and the average tons harvested per hectare (c), respectively.

"Cherokee" (Figure 3). This represents an oligopoly issue, as according to the ProNacE (National Strategic Programs) "Soberanía alimentaria" a small group of companies sell the inputs for the agricultural cycle, which disadvantages self-consumption production and product commercialization (CONAHCYT, 2022). The reduction of self-production leads to increased production costs, as each cycle requires purchasing seed due to the fact that hybrid cultivars are male-sterile.

The government support program PROCAMPO, now called "Producción para el Bienestar" (PpB), has mainly focused on the acquisition of fertilizers and seeds, and has been

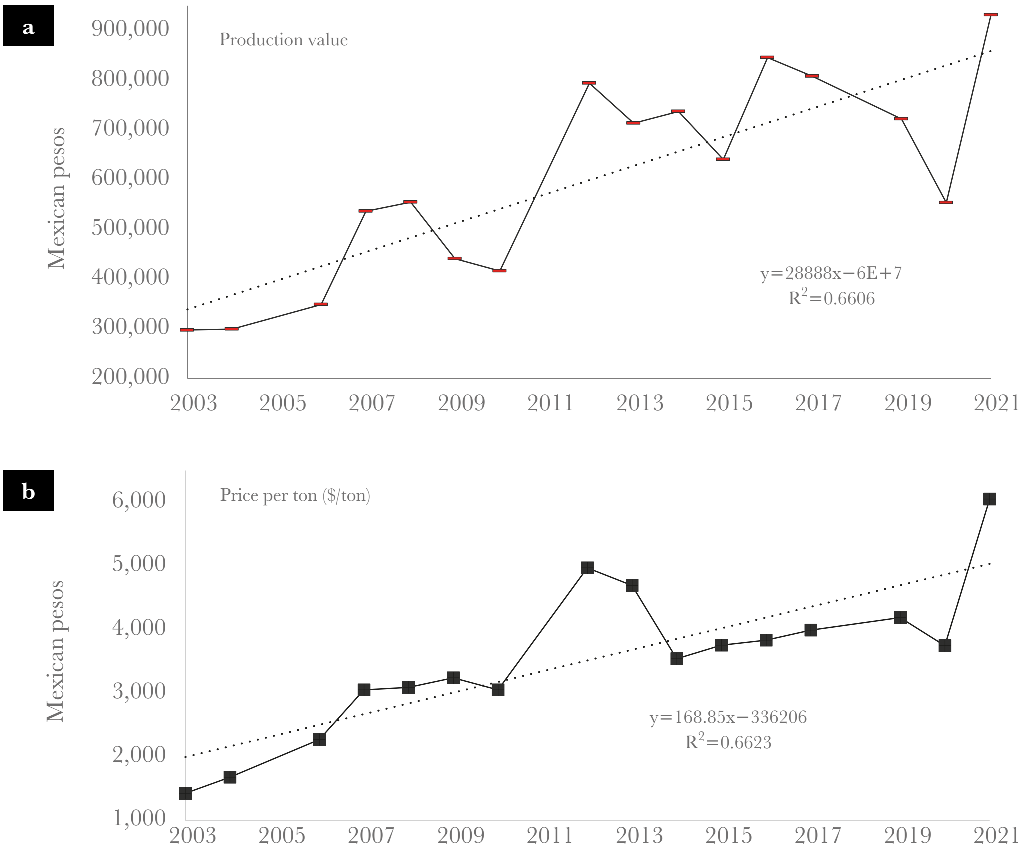

Figure 2. Variation in production value (a) and price per ton of corn (b) during the years 2003-2021 in the Valle de Bravo district, State of Mexico. Both graphs express their values in Mexican pesos.

received by 84% of the surveyed farmers. However, 96% of the beneficiaries considered that the amounts provided did not cover all the costs associated with agricultural production. The subsidies granted amounted to $1,600.00 pesos per hectare, representing 12.29% of the total maize production value. The government support program PROCAMPO,

Table 2. Historical comparison by RDD of the State of Mexico in corn production (2003-2021).

	District	Sown area (ha)	Harvested area (ha)	Production value (Thousands of $ mxn)	Production (ton)	Yield (ton ha^{-1})	Price per ton ($ ton^{-1})
					***	***	ns
1	Toluca	122598.79	115359.25	1467274.57	455330.40b	3.95a	3246.4a
2	Zumpango	44987.24	41812.99	361885.66	109413.94c	2.60bc	3367.32a
3	Texcoco	34784.52	34404.58	379774.37	112420.80c	3.28ab	3333.56a
4	Tejupilco	49716.79	49574.38	469165.08	124815.98c	2.50c	3880.12a
5	Atlacomulco	154715.52	148832.17	1797786.11	542908.81a	3.58a	3225.15a
6	Coatepec	33315.17	303094.65	392374.83	110777.31c	3.35a	3478.87a
7	Valle de Bravo	49461.24	47917.72	555683.12	158885.71c	3.33ab	3493.20a
8	Jilotepec	49181.17	45899.85	494451.72	151623.98c	3.22abc	3282.52a

Means with different letters in a column are statistically different ($p \leq 0.05$). *** $p \leq 0.001$, ** $p \leq 0.01$, * $p \leq 0.05$, ns: not significant.

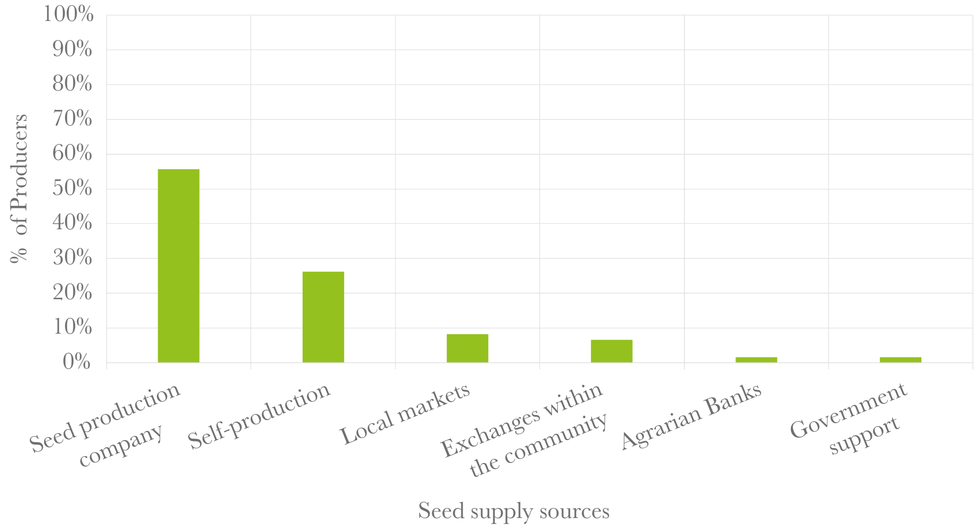

Figure 3. Sources of seed supply for farmers in the DDR 7 "Valle de Bravo."

now called "Producción para el Bienestar" (PpB), has mainly focused on the acquisition of fertilizers and seeds, and has been received by 84% of the surveyed farmers. However, 96% of the beneficiaries considered that the amounts provided did not cover all the costs associated with agricultural production. The subsidies granted amounted to $1,600.00 pesos per hectare, representing 12.29% of the total maize production value. The divided opinions on the usefulness of technical advice reflect the need for greater dissemination and quality in its delivery, with 19% of farmers perceiving it as exclusively focused on product sales. In this regard, according to CEDRSSA (2020b), farmers face multiple productivity challenges that require a comprehensive strategy, suggesting coordination between the Production for Wellbeing Program (PpB) and other SADER programs to address these difficulties and move towards food self-sufficiency. CONEVAL (2020), on the other hand, proposes allocating more resources to the PpB to improve access to training, technical assistance, and formal credit, as programs focused solely on economic incentives, such as PROAGRO, have not shown a significant increase in agricultural yield.

Financing for corn production, according to producers, comes primarily from their own resources (54%), combined with public subsidies (40%), and through research institutions (6%). However, despite the efforts made by the producers, 98% of them believed that the prices are inadequate as they leave little profit margin. Additionally, 24% thought that a fair price would be $10,000.00 pesos per ton of grain, followed by $7,000.00 and $8,000.00 pesos (12% each), while 10% believed a fair price would be $25,000.00 pesos per ton. The guaranteed price for a ton of corn in 2022 was $6,278.00 pesos, according to the Diario Oficial de la Federación (SADER, 2022). It is important to note that 3% of the respondents believe that the liberalization of corn prices is ideal; however, this may not be the best strategy, as leaving the price to the discretion of sellers would automatically raise the price of the crop and, consequently, the price of products made from the grain. At the same time, the cost of food products derived directly and indirectly from corn, such as meat, would increase, creating a chain reaction of rising prices across various products. Ultimately, according to the interviewed producers, the factors that they consider most difficult for the development of agricultural activities are: the high costs of seeds and fertilizers (76%), followed by the high risks and low profitability of the crop (68%), as well as the lack of financial resources for inputs (58%) (Table 3).

Table 3. Factors hindering the development of agricultural activities.

Factors	High	Low	Medium	Irrelevant	Total
lack of technological information.	34%	30%	28%	8%	100%
High risk and low profitability of the crop.	68%	6%	26%	0%	100%
Inadequate infrastructure.	50%	4%	26%	20%	100%
Presence of intermediaries.	52%	16%	14%	18%	100%
Lack of resources for inputs.	58%	4%	34%	4%	100%
High seed and fertilizer costs.	76%	8%	12%	4%	100%
Lack of access to inputs and machinery.	28%	22%	34%	16%	100%
Weather claims.	62%	14%	24%	0%	100%
Difficulty in accessing financial support.	16%	32%	22%	30%	100%
Other Factors.	0%	4%	0%	96%	100%

CONCLUSIONS

The disparity between the supply and demand of maize in the State of Mexico remains a significant issue, leading to a heavy reliance on imports, especially from the United States and Brazil. This highlights the need to strengthen domestic production to ensure food security. The DDR 7 "Valle de Bravo" has experienced a gradual increase in maize yields, partly due to programs like the Sustainable Modernization of Traditional Agriculture. However, yields remain lower than in other leading production states, such as Jalisco and Sinaloa.

The decrease in the area dedicated to maize in the DDR 7 reflects a shift in farmers' preferences towards more profitable crops, such as oats and vegetables, due to high input costs and low maize sale prices. Farmers face challenges that require a comprehensive strategy to increase productivity, reduce costs, and promote crop diversification to ensure the sustainability of the sector.

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