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WPSR No. 17A

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* Principal Research Assistant, Economics Program, CIMMYT, Mexico.

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Contents

Abstract

This report presents results of the analysis of data from a survey conducted during the fall-winter 1993/94 crop cycle in the Yaqui Valley of northwestern Mexico. It describes the agronomic practices of wheat producers and details the agronomic factors that influence wheat yield. Weed control appears to be the most significant factor in the yield function. Weed infestation is reduced if wheat is planted on beds, a practice that Yaqui Valley farmers have been adopting in increasing numbers since 1980. Results of this study indicate that bed planting, compared to traditional methods of planting in corrugations or on the flat *(me/gas),* permits better weed control and employs lower quantities of inputs such as fertilizers, pesticides, seed, and water, thus reducing production costs. Together, improved weed control and reduced input use lead to a significant difference in profits in favor of bed planting. Although the bed planting technology is used more frequently on clay soils, which is where the highest profits are achieved, it is also profitable on alluvial soils. The reduction in agrochemical use is beneficial to the environment, and soil and water conservation are improved by improving water management and reducing the volume of irrigation water. Among the possible limitations of the bed planting technology are the lack of machinery and proper tools to manage beds, and the additional time that bed planting requires. However, the advantages of bed planting suggest that more farmers are likely to adopt the technology, which means that farmers would benefit from more technical support from extension in disseminating information about the agronomic and economic advantages of the technology.

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The Adoption of Bed Planting of Wheat in the Yaqui Valley, Sonora, Mexico

Pedro Aquino

1. Introduction

The current economic milieu of developing countries and its effects on the agricultural sector, particularly in the search for sustainable agricultural systems, has changed cultivation patterns as well as agricultural practices aimed at increasing productivity and improving the use of natural resources. By monitoring and analyzing technical change, we can gauge the effectiveness of technology development and transfer processes and implement agricultural programs that meet the needs of farmers.

Farmers in Mexico's Yaqui Valley, like their counterparts throughout the developing world, face new conditions brought about by such changes in sectoral policy as the lowering of trade barriers, restrictions on credit, limits on guaranteed prices, and reduced subsides on inputs such as seed, fertilizer, and irrigation water. The need to conserve the natural resource base for agriculture is also becoming more acute. To respond effectively to these new conditions, farmers require technological options that maintain or increase productivity, reduce costs, and maintain production systems in a sustainable manner. Technological innovations must be monitored continuously to ensure that they meet these criteria. This report examines the role of a particular crop management innovation – planting wheat on beds -- in enabling farmers to meet the challenges of a changing socioeconomic and agroecological environment.

Over the years, the CIMMYT Economics Program has monitored patterns of technology adoption in the Yaqui Valley through surveys of wheat production practices. Surveys were conducted in 1981, 1982, 1987, 1989, and 1991; this study draws on data from the latest survey, which took place in the Fall-Winter 1993/94 cycle. For this survey, direct interviews were carried out in the fields of 85 wheat farmers. The survey data were the starting point for this study, which has several objectives:

1. Describe farmers' wheat cultivation practices.
2. Determine which agronomic factors and socioeconomic characteristics of farmers influence wheat yield.

3. Conduct a comparative analysis of yield factors in relation to planting method (beds, corrugations, and *melgas*).
4. Analyze the factors influencing adoption of bed planting.

2. Agroclimatic and Socioeconomic Characteristics of the Study Area

The Importance of Wheat in the Yaqui Valley

Wheat production in the Yaqui Valley is of regional as well as national importance. During the 1993/94 cycle, 223,296 ha were planted in the Yaqui Valley. Of this area, 152,751 ha were planted to wheat for a total production of 823,399 t, equivalent to approximately 22% of Mexico's 3,811,091 t wheat production. The value of wheat production represented 55% of the total value of agricultural production in the Yaqui Valley.

Temperature

Meteorological data indicate that during the 1993/94 cycle maximum and minimum temperatures were similar to the average for preceding years (Figure 2.1), except in April and May, which had higher temperatures than normal.

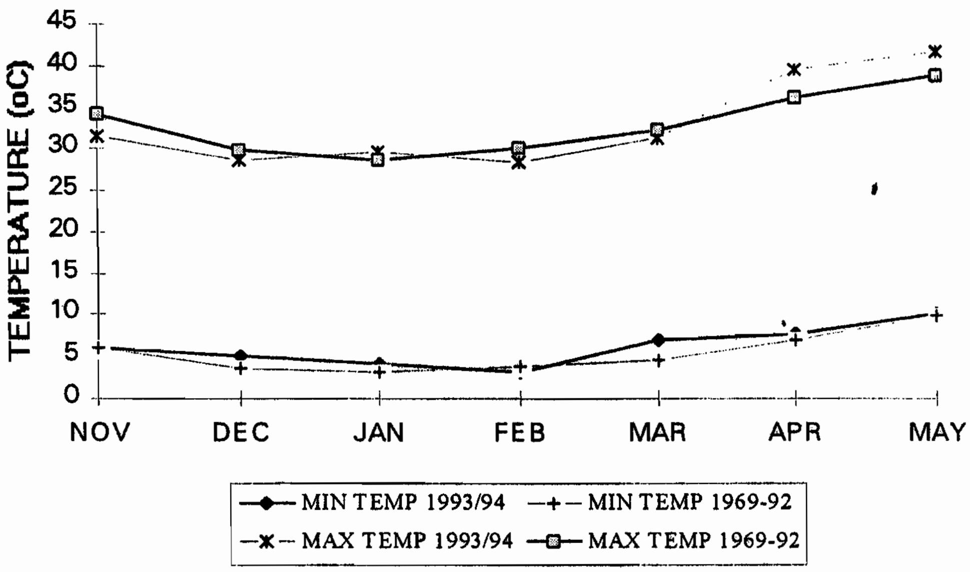

Figure 2.1. Maximum and minimum temperatures for the 1993/94 cycle and the period 1969-92.

Precipitation

Rain fell only in November and December, with the highest quantity in the first days of November (Figure 2.2). In some cases, the rain substituted for the pre-planting irrigation. In other years, rainfall or lack of rainfall in November-December has been known to delay planting; this is discussed in greater detail later.

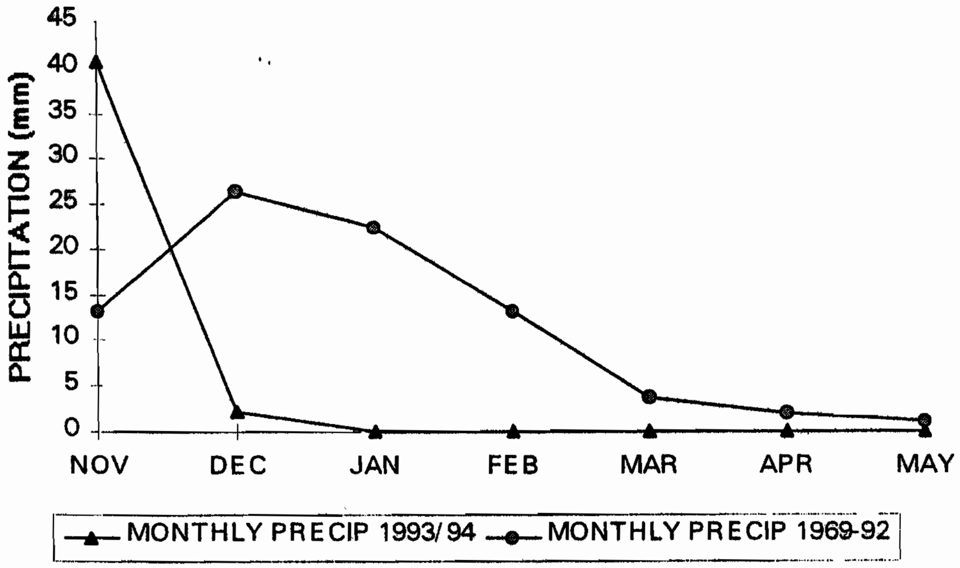

Figure 2.2. Average monthly precipitation 1993/94 cycle and 1969-92 period.

Soils

The distribution of producers by soil type is shown in Table 2.1. The data in the table clearly show that heavy, alluvial soils and deep clay soils occupy the greatest area in the Yaqui Valley. Although the soil classification of CIRNO (Centro de Investigación Regional del Noroeste) is used in this table, throughout the remainder of this report a simplified classification of clay and alluvial soil types is used.

Table 2.1. Soil types in fields of survey farmers

Soil type	Number of farmers	Percentage of farmers
Deep clay	37	43.5
Heavy alluvial	27	31.8
Compacted clay	11	12.9
Heavy alluvial with salts	7	8.2
Light alluvial	2	2.4
Light alluvial with salts	1	1.2

Planting Method

Under the traditional practice, the land is covered completely with wheat plants, with the objective of enabling wheat to compete successfully with weeds for water, space, light, and nutrients. In contrast, the objective of planting wheat on beds is to leave enough space between the plants so that people and machinery can perform operations critical to crop development, the most important of which is weed control (mechanical and manual). Four planting methods are practiced by wheat farmers in the Yaqui Valley:

1. *Melgas*. This is the traditional system of planting wheat on flat seedbeds. Wheat seed is either broadcast and then incorporated (generally with a harrow), or a small grain seeder is used to deposit seed continuously in rows. Borders are raised to form the *melgas*, the size and shape of which depend on how well the field has been levelled. The farmer can subdivide the field into straight *melgas* on levelled fields or into *melgas* that follow the contour of the land (*curvas de nivel*).
2. *Corrugations*. Wheat is seeded as for *melgas*, either broadcast or with a small grain seeder. However, instead of raising borders, farmers make a shallow furrow to carry irrigation water.
3. *Planting on beds*. Two bed planting methods were originally recommended: the use of a narrow bed (50-60 cm) with one row on the bed, or the use of a wide bed (80-100 cm) with two rows on the bed. Nevertheless, farmers have adapted these methods to include three and sometimes four rows on the surface of the bed, which makes it impossible to introduce equipment between the rows. This procedure reduces the efficacy of weed control.
4. *An adaptation or variation* of the previous technique is to sow an additional row at the bottom of the furrow. Farmers' objective in doing so is to create high wheat populations that will compete successfully with weeds for water, nutrients, and light. However, with this technique, the fundamental objective of bed planting is lost.

For the statistical analysis, planting methods were grouped into *melgas*, corrugations,[1] and rows on the bed, because these are the most common methods in the study area. The classification scheme is shown in Table 2.2. The number of rows for the bed planting method corresponds to the technical recommendations provided by the Yaqui Valley Experiment Station (CEVY). As

[1] Corrugations include the planting variations with three rows on the bed and one in the furrow (described in 3 and 4 above), because agronomic management for these practices is similar to the management of corrugations. In both practices, the furrow is used principally to conduct water and not to facilitate mechanical cultivation.

indicated earlier, farmers actually use variations on these practices, adapting them to suit their own objectives or needs. Throughout this report, "planting in rows" or "bed planting" refers to planting in rows on a bed. "Cultivation" refers to weeding or mechanical cultivation.

Table 2.2. Planting methods in the Yaqui Valley

Traditional	Nontraditional
Melgas	Beds
Straight	Narrow (one row on the bed)
Broadcast	Wide (two rows on the bed)
Rows	
Contour (*Curva de nivel*)	
Broadcast	
Rows	
Corrugations	
Broadcast	
Rows	
Beds	
Three rows on the bed and one in the furrow	

Land Tenure

Among the survey farmers, 31% were *ejidatarios* (owners of communal land), 28% were private landowners, and the remaining 41% were tenants on either *ejido* or other land (Table 2.3). The relatively high percentage of farmers who reported renting land could be a result of recent modifications to Article 27 of the Constitution and related agrarian legislation. Renting of *ejido* land has been legal since 1992, so farmers are less reluctant to discuss their rental arrangements. In previous farmer surveys the percentage of renters was always less than 9%, although it is known that many people actually rented land during this time.

Table 2.3. Land tenure arrangements of survey farmers

Tenure	Number of farmers	Percentage of farmers
Individual *ejido*	19	22.4
Collective *ejido*	7	8.2
Privately owned land	24	28.2
Rented individual *ejido*	17	20.0
Rented collective *ejido*	8	9.4
Rented privately owned land	10	11.8

Credit and Technical Assistance

All of the producers surveyed relied on credit, obtained from three main sources: credit unions (45%), private banks (42%), and BANRURAL, a government bank (13%). Credit unions and private banks provided credit for all renters and 96% of private landowners, whereas a higher percentage of *ejidatarios* (communal landowners) was served by BANRURAL (38%) (Table 2.4). The small proportion of farmers receiving credit from BANRURAL reflects the new credit policies of this agency, which focuses on providing subsidized credit to lower income producers with productive potential. In 1990, BANRURAL began transferring higher income farmers, for whom preferential credit was no longer justified, to private banks for assistance.

Sixty-nine percent of the farmers said they relied on technical assistance.[2] The percentages of farmers receiving such assistance, according to institutions that supplied assistance, are: credit unions (51%), private banks (35%), and BANRURAL (14%). The *ejido* sector received the most technical assistance; 85% of this type of producer received attention, followed by 69% of renters and 54% of private landowners. In general, farmers financed by credit unions, whether individually or as part of an association, receive agricultural insurance coverage from an insurance fund, which in turn provides technical assistance. This partly explains the high percentage of farmers receiving technical assistance. In addition, producers who receive assistance from BANRURAL and private banks receive a fixed amount of credit for contracting technical assistance services; however, contracting for such assistance is now a personal responsibility. Distributors of agrochemicals also provide some technical assistance, and in other instances the farmers themselves are trained agronomists.

Table 2.4. Percentage of farmers receiving credit from a financing agency, by land tenure arrangement

	Credit institution		
Tenure	**Credit union**	**BANRURAL**	**Private bank**
Ejido	35	38	27
Privately owned land	46	4	50
Rented	51	..	49

Machinery

Eighty percent of the producers surveyed have their own machinery, and the remaining 20% hire machinery services for various tasks. Private landowners and renters own machinery in the same proportion (83%), whereas 73% of *ejidatarios* have their own machinery (Table 2.5).

2 "Technical assistance" means that technicians supply farmers, in an organized fashion, with direction and other kinds of support related to production planning, the use of credit and inputs, and marketing and marketing organizations, thus inducing technological innovation among farmers.

Table 2.5. Ownership of machinery (% of producers), by land tenure arrangement

Tenure	Machinery	
	Own	Contract
Ejidal	73	27
Privately owned land owners	83	17
Rented	83	17

3. Agricultural Practices

Soil Preparation

In the 1993-94 cycle, 35% of producers subsoiled and 26% plowed their land in preparation for planting wheat. Additionally, 19% of the farmers leveled with a land plane, and 60% used the *tablón* method, in which large pieces of wood are used to level the field.

Planting Method

Almost all wheat is sown into moist soil after a pre-planting irrigation. Ninety-four percent of the farmers used this practice, which aims to eliminate the large quantity of first-generation weeds by preparing the seed bed. Only 6% of the producers used dry planting. The most common planting method was rows on beds (55%), followed by corrugations (25%) and *melgas* (20%) (Table 3.1). For the bed planting method, the average distance between beds turned out to be 76 cm, and the distance between rows was 21 cm. The average number of rows on the ridge was three, which indicates the extent to which farmers vary the technical recommendations.[3] In this case, the distances between beds and between rows are below those recommended and the number of rows is above the optimum, which does not allow for efficient mechanical weed control and could lead to a reduction in yield.

Table 3.1. Distribution of farmers by planting method

Planting method	Number of farmers	Percentage of farmers
Beds	47	55.3
Corrugations	21	24.7
Melgas	17	20.0

[3] CEVY recommends that farmers using a distance of 50-60 cm between beds should plant one row. For planting two rows, the distance between beds should vary between 80 and 100 cm and there should be 25-45 cm between rows, depending on the crop rotation and the availability of equipment.

There is a relationship between choice of planting method and soil type (Table 3.2). Bed planting was done mainly on clay soils (72%), as was planting in corrugations (52%), whereas *melgas* were more common on alluvial soils (82%). Clay soils require a greater volume of water, and bed planting permits better management and savings of irrigation water.

Planting Date

In the 1993-94 cycle, 66% of survey farmers planted wheat between 15 November and 15 December, the optimal recommended planting period. The remaining 34% sowed later, by 5 January at the latest. Late sowing was a function of weather, particularly rainfall. Rain during the optimal planting period prevents machinery from entering the field to plant. On the other hand, when there is no rain, the demand for water for the pre-planting irrigation is very high and can also delay sowing. The average planting date was 10 December.

Seed Rate

The survey results show that in general less seed was required for bed planting than for corrugations and *melgas* (Table 3.3). On average, farmers used 134 kg/ha of seed. In all cases, farmers used higher seed rates than those recommended by CIRNO -- 100-120 kg/ha for traditional methods (*melgas* and corrugations) and 50-60 kg/ha for bed planting.

Table 3.2. Planting method by soil type (% of farmers)

	Soil type	
Planting method	**Clay**	**Alluvial**
Beds	72.3	27.7
Corrugations	52.4	47.6
Melgas	17.6	82.4

Note: χ^2= 15.38; d.f. = 2; p = .00046.

Table 3.3. Seed rate by planting method

Planting method	**Number of farmers**	**Seed rate (kg/ha)**
Beds	47	118.38a
Corrugations	21	139.57b
Melgas	17	168.82c

Note: Different letters indicate significant difference (Duncan (0.05), within-column comparison.

Seed rates also varied by soil type. In clay soils, less seed was used for bed planting than for the traditional planting methods (corrugations and *melgas*), although the difference was only significant between bed planting and *melgas* (Table 3.4). In alluvial soils, farmers also used less seed for bed planting than for traditional methods.

Plant Density

Plant density or population -- the plant coverage on the land -- is not directly related to seed rate (the quantity of seed sown). Densities classified as good or adequate were obtained with lower seed rates, and higher seed rates actually resulted in poorer densities (Table 3.5).

Agronomic observations by enumerators indicate that 87% of the farmers who employed bed planting obtained a good plant population, while only 67% of the producers who used corrugations and 56% of those who planted in *melgas* obtained good populations (Table 3.6). The percentage of farmers who had good plant populations also varied by soil type; good populations were more common in clay soils than in alluvial soils (Table 3.7).

Table 3.4. Seed rate by soil type and planting method

	Clay soils		**Alluvial soils**	
Planting method	**Number of farmers**	**Seed (kg/ha)**	**Number of farmers**	**Seed (kg/ha)**
Beds	34	114.6a	13	128.2a
Corrugations	11	129.4a	10	150.8ab
Melgas	3	168.3b	14	168.9b

Note: Different letters indicate significant difference (Duncan (0.05), within-column comparison.

Table 3.5. Plant density in relation to seed rate

Plant density	**Seed rate (kg/ha)**
Good	131.44a
Adequate	134.67a
Poor	190.00b

Note: Different letters indicate significant difference (Duncan (0.05), within-column comparison.

Table 3.6. Plant density by planting method

	Plant density (%farmers)		
Planting method	**Good**	Adequate	**Poor**
Beds	87.0	13.0	..
Corrugations	66.7	33.3	..
Melgas	56.3	31.3	12.5

Table 3.7 Plant density by soil type

	Plant density (%farmers)		
Soil type	**Good**	Adequate	**Poor**
Clay	85.1	12.8	2.1
Alluvial	63.9	33.3	2.8

Table 3.8. Plant density in clay soils by planting method

Planting method	Plant density in clay soils (% farmers)		
	Good	Adequate	Poor
Beds	93.9	6.1	..
Corrugations	63.6	36.4	..
Melgas	66.7	..	33.3

Table 3.9. Plant density in alluvial soils by planting method

Planting method	Plant density in alluvial soils (% farmers)		
	Good	Adequate	Poor
Beds	69.2	30.8	..
Corrugations	70.0	30.0	..
Melgas	53.8	38.5	7.7

Table 3.10. Plant density by machinery ownership

Machinery	Plant density (%farmers)		
	Good	Adequate	Poor
Own	81.8	18.2	..
Contract	52.9	35.3	11.8

In clay soils, most producers who used bed planting (94%) obtained a good plant density. Only 64% of those who sowed in corrugations obtained good densities, and 67% of those who planted in *melgas*. These data imply that better coverage of the planting area occurred when farmers used beds (Table 3.8).

The percentage of farmers who obtained a good density in alluvial soils was similar. Sixty-nine percent of farmers who planted on beds achieved a good plant population, whereas 70% of those who used corrugations did so. Among farmers who planted in *melgas,* only 54% had a good population (Table 3.9).

In general, when farmers had their own machinery, they achieved good densities. Among producers who hired machinery services, the percentage of adequate and poor densities was higher (Table 3.10).

Varieties

The most commonly used varieties were Rayón (33%), Altar (28%), Aconchi (15%), and Tepoca (11%). The varieties Oasis, Cucurpe, Bacanora, Opata, and Pápago (in descending order) were used in smaller proportions by 13% of producers (Table 3.11).

In the 1993/94 cycle, 57% of survey farmers planted bread wheat, while the other 43% sowed durum varieties. These varieties were largely of intermediate and late maturity (46% in each maturity class). Only 8% of farmers grew early maturing varieties. Durum varieties were virtually all late maturing types (97%), whereas the bread wheats were mostly of intermediate maturity (80%). It is worth pointing out that 61% of all producers planted more than one variety of wheat, for an average of two varieties per farmer. Seed was acquired principally from private commercial houses (41%) and from credit unions (24%). The remaining 35% of the seed used by survey farmers was supplied by other organizations, such as PRONASE, and farmers who produce their own seed.

Irrigation Practices

The farmers surveyed applied an average of 5.3 irrigations during the 1993/94 cycle. The majority of farmers receive water from canals, which are cleaned an average of twice during the growing cycle, either manually (29%), mechanically (22%), chemically (12%), or using a combination of methods. Only 2% of the farmers used pump irrigation. The most common method of irrigation was through beds and corrugations (79%), followed by *melgas* (18%) (Table 3.12).

Farmers who planted on beds in clay soils had a lower average number of irrigations. Although the difference was only statistically significant between beds and *melgas*, it would seem to indicate that less irrigation water was needed for beds (Table 3.13). Unlike clay soils, in alluvial soils the number of irrigations was not significantly different for the different planting methods. On both soil types, similar volumes of irrigation water were used. The number of irrigations used with the bed planting method is the same for both soil types, even though clay soils require more irrigation water. This indicates that the quantity of irrigation water used on clay soils was reduced.

Table 3.11. Wheat varieties grown by farmers in the Yaqui Valley, Mexico, 1993/94

Variety	Number of farmers	Percentage of farmers
Rayón	28	32.9
Altar	24	28.2
Aconchi	13	15.3
Tepoca	9	10.6
Oasis	5	5.9
Cucurpe	2	2.4
Bacanora	2	2.4
Pápago	1	1.2
Opata	1	1.2

Table 3.12. Irrigation methods used by survey farmers

Irrigation method	Number of farmers	Percentage of farmers
Beds	47	55.3
Corrugations	21	24.7
Straight *melgas*	15	17.6
Melgas on the contour	2	2.4

Fertilization

Farmers applied an average of 251 kg/ha of nitrogen to wheat, although the range varied from 140 to 382 kg/ha. Application methods included injection of fertilizer into the soil, bubbling liquid through irrigation water, and applying granules at planting. Nitrogen gas was used by 84% of the producers, whereas urea was the most commonly used solid fertilizer (42%). Total nitrogen application was greater (although not significantly so) under traditional planting methods compared to planting on beds. On average, farmers using corrugations applied an additional 24 kg/ha and those using *melgas* an additional 18 kg/ha of nitrogen (Table 3.14):

Sixty-six percent of farmers applied phosphorous. The average rate was 35 kg/ha P_2O_5 (this includes producers who applied no phosphorus). Application rates ranged from 20 to 156 kg/ha. The principal sources of the nutrient were triple superphosphate and diammonium phosphate (both containing 46% P_2O_5), used by 39% of producers, as well as liquid phosphorous, used by 14% of producers. The overall application of phosphorous did not differ by planting method (Table 3.14).

An analysis of fertilizer application by soil type shows similar results. Certainly, on both soil types, the amounts of nitrogen applied were lower for bed planting than for corrugations and *melgas* (Table 3.15). Phosphorous applications were higher for bed planting (Table 3.16), but the differences were not significant.

Table 3.13. Average number of irrigations by soil type and planting method

Planting method	Clay soils		Alluvial soils	
	Number of farmers	Average number of irrigations	Number of farmers	Average number of irrigations
Beds	34	5.2a	13	5.2a
Corrugations	11	5.6b	10	5.4a
Melgas	3	5.3ab	14	4.9a

Note: Different letters indicate significant difference (Duncan (0.05), within-column comparison.

Table 3.14. Nitrogen and phosphorus application on wheat, survey farmers, Yaqui Valley, 1993/94

Planting method	Nitrogen application		Phosphorus application	
	Number of farmers	N rate (kg/ha)	Number of farmers	P_2O_5 rate (kg/ha)
Beds	47	241.7a	47	36.9a
Corrugations	21	265.7a	21	35.4a
Melgas	17	259.8a	17	27.3a

Note: Different letters indicate significant difference (Duncan (0.05), within-column comparison.

Table 3.15. Nitrogen application by soil type and planting method

Planting method	Clay soils		Alluvial soils	
	Number of farmers	N (kg/ha)	Number of farmers	N (kg/ha)
Beds	34	239.2a	13	248.2a
Corrugations	11	260.9a	10	270.9a
Melgas	3	260.0a	14	259.8a

Note: Different letters indicate significant difference (Duncan (0.05), within-column comparison.

Table 3.16. Phosphorus application by soil type and planting method

Planting method	Clay soils		Alluvial soils	
	Number of farmers	P_2O_5 (kg/ha)	Number of farmers	P_2O_5 (kg/ha)
Beds	34	35.2a	13	41.4a
Corrugations	11	33.0a	10	38.0a
Melgas	3	32.0a	14	26.3a

Note: Different letters indicate significant difference (Duncan (0.05), within-column comparison.

Table 3.17. Fertilizer use now compared with five years ago

How much fertilizer?	Number of farmers	Yield (kg/ha)
More	37	5,605.11a
Less	10	5,466.40a
Same	38	5,329.89a

Note: Data followed by the same letters show no significant difference (Duncan (0.05), within-column comparison.

The quantity of applied nitrogen was above the level recommended by CIRNO. The highest rate of nitrogen application recommended by CIRNO is for deep clay soils (160 kg/ha of nitrogen). (Application rates for pebbly and compacted clay soils are 85 kg/ha and 115 kg/ha, respectively.) For light alluvial soils, CIRNO has recommended 130 kg/ha of nitrogen; for heavy alluvial soils, the rate is 175 kg/ha.

Eighty-nine percent of producers applied fertilizer between two and four times, 4% applied it only once, and the remaining 7% applied fertilizer five to six times, resulting in a general average of three applications. Forty-eight percent of survey farmers carried out at least one application of fertilizer injected into the soil, 94% bubbled in the irrigation water, and 68% applied in granulated form.

Of the producers surveyed, 45% believed that they used more fertilizer at the time of the survey than five years previously. The majority said they did so to obtain better yields. Forty-three percent of the farmers said they still used the same amount of fertilizer, because they believed it helped them obtain good yields, whereas the remaining 12% said they used less fertilizer because they used it principally in the furrow. There were differences in yield between the three farmer categories, but they were not statistically significant (Table 3.17).

Weed Control

Although 32% of survey farmers said they had experienced grassy weed infestations in their wheat, and 22% said they had broadleaf weed infestations in wheat, no generalization can be made about the use of agrochemicals for weed control, because 11% of farmers used agrochemicals to control grassy weeds, 7% used them on broadleaf weeds, and 3% used them to control both weed types. Nevertheless, 71% of those surveyed weeded manually, and 38% carried out at least one mechanical weeding. Manual weeding required 1.8 days/ha on average (which included farmers who did no manual weeding), although the range varied from 0.2 to 16 days/ha.

Weed infestations were more prevalent in alluvial soils: 36% of producers had problems with broadleaf weeds on alluvial soils, while 42% reported grassy weeds, in contrast to 11% and 25%, respectively, in clay soils (Table 3.18). Herbicides were applied in similar proportions on both soil types (21% of farmers with clay soils applied herbicides, compared to 22% with alluvial soils).

Of the producers who used traditional planting methods, 38% had grassy weed infestations and 30% broadleaf weed infestations, while only 28% and 15% of farmers who planted on beds reported problems with grassy and broadleaf weeds, respectively.

In general, farmers observed that wheat fields were free of broadleaf weeds when the wheat crop was rotated with soybeans (Table 3.19).

Table 3.18. Weed infestation level by weed and soil type (percentage of farmers reporting)

	Grassy weed infestation level				Broadleaf weed infestation level		
Soil type	**Free**	**Light**	**Moderate**	**Severe**	**Free**	**Light**	**Moderate**
Clay	74.5	14.9	2.1	8.5	89.4	4.3	6.4
Alluvial	58.3	16.7	13.9	11.1	63.9	19.4	16.7

Table 3.19. Broadleaf weed infestation by previous crop in rotation (percentage of farmers reporting)

	Level of broadleaf weed infestation		
Previous crop	**Free**	**Light**	**Moderate**
Soybeans	82.4	7.4	10.3
Other	57.1	28.6	14.3

Table 3.20. Levels of grassy weed infestation in relation to mechanical cultivation

Mechanical cultivation	Grassy weed infestation level			
	Free	Light	Moderate	Severe
No	67.3	17.3	5.8	9.6
Yes	67.7	12.9	9.7	9.7

Table 3.21. Levels of grassy weed infestation in relation to manual weeding

Manual weeding	Grassy weed infestation level			
	Free	Light	Moderate	Severe
No	70.8	8.3	..	20.8
Yes	66.1	18.6	10.2	5.1

Table 3.22. Levels of grassy weed infestation in relation to herbicide application

Herbicide application	Grassy weed infestation level			
	Free	Light	Moderate	Severe
No	74.2	12.1	7.6	6.1
Yes	41.2	29.4	5.9	23.5

Levels of grassy weed infestation, which is of greater importance in the Yaqui Valley because of the magnitude of the damage these weeds cause, are similar regardless of whether or not mechanical cultivation is done (Table 3.20). Severe grassy weed infestations are lower when manual weeding is done (Table 3.21). Among farmers who used herbicides, the proportion of severe grassy weed infestations was higher and a smaller percentage of fields were free of infestation (Table 3.22). These results indicate that manual weeding and mechanical cultivation are complementary and produce better results in the control of grassy weeds compared to the use of herbicides alone.

Pest and Disease Control

In general, farmers use very little insecticide because most pests that attack wheat in this region are seasonal, causing damage only when they appear. Under normal conditions, natural biological control is sufficient to control pests, principally plant lice. In the 1993/94 cycle, there were no important insect pests, and only 2% of the farmers carried out any insecticide application.

Only farmers who produce grain for seed apply fungicide. The primary form of disease control in the Yaqui Valley is plant breeding for disease resistance. In accordance with reports by survey farmers, no occurrence of Karnal bunt was found in the 1993-94 cycle. Although this disease does not affect wheat yields, it diminishes grain quality, which leads to discounts in the price paid to the producer.

Residue Management

In the 1992/93 cycle, residues from the wheat harvest were burned by 95% of the farmers. This practice is deeply entrenched. When asked how they would manage the residues from the 1993/94 cycle, 94% of farmers answered that they would continue burning it. Most respondents (75%) stated that they burn residues because of the short time available to prepare land and establish the crop for the spring-summer cycle.

Harvest and Establishment of Subsequent Crop

Among survey farmers, 37% own a combine for harvesting wheat. Once the harvest is finished, the residue is burnt or incorporated so that the subsequent crop can be established rapidly. The subsequent crop is generally soybeans (Table 3.23).

Yields

The average yield of wheat grain was 5,466 kg/ha on a harvested area averaging 2,149 ha, for a net production of 11,968 t. Although the average yield expected by farmers was lower than what they actually obtained, expected and actual yields did not differ significantly (Table 3.24), probably because producers have a fairly accurate knowledge of agricultural conditions and know what to expect.

With regard to production incentives, 99% of the farmers received production bonuses for the wheat crop in two categories: direct support in cash, for specified weight, from the state government (81%) and for grain quality (protein content) from the industries that buy wheat grain (18%).

Table 3.23. Previous crop in rotation (% of farmers)

Crop	Number of farmers	Percentage of farmers
Soybeans	70	83.3
Maize	7	8.3
Cotton	3	3.6
Other	3	3.6
Fallow	1	1.2

Table 3.24. Farmers' expected and actual wheat yields, Yaqui Valley, 1993/94

	Yield (kg/ha)
Estimated	5,301.37
Obtained	5,453.26

Note: $t = -1.68$; d.f. = 72; p = n.s.

An examination of wheat yields by planting method shows a favorable difference in yield with bed planting. The difference in yields between bed planting and corrugations is not significant, but the difference between these two technologies and *melgas* is marked (Table 3.25).

Machinery ownership is associated with higher yields, which can be explained by the fact that machinery owners can perform agricultural tasks at the optimal time for the development of the crop. Nevertheless, the difference is not significant (Table 3.26).

A comparison of average yields by planting date indicates that farmers who sowed wheat within the optimal period obtained about 554 kg/ha more grain than farmers who sowed later (Table 3.27). This information confirms the results of agronomic research, which has shown that sowing within the optimal period favors an increase in yield.

Plant density seems to have a strong influence on yields, as shown by the significant differences between farmer groups classified by the plant density of their wheat crop. Farmers whose wheat fields had "good" planting densities obtained higher yields than those who had fields with "adequate" densities, while those with the lowest yields also had "poor" densities (Table 3.28).

Table 3.25. Wheat yields by planting method

Planting method	Number of farmers	Yield (kg/ha)
Beds	47	5,615.21a
Corrugations	21	5,570.38a
Melgas	17	4,923.29b

Note: Different letters indicate significant difference (Duncan (0.05), within-column comparison.

Table 3.26. Wheat yields by machinery ownership

Machinery	Number of farmers	Yield (kg/ha))
Owns	68	5,555.28
Contracts	17	5,107.65

Note: $t = 1.79$; d.f. = 83; p = n.s.

Table 3.27. Wheat yields by planting date

Planting date	Number of farmers	Yield (kg/ha)
Optimal (15 Nov.-15 Dec.)	55	5,665.38
Beyond optimal period	29	5,111.83

Note: $t = -2.37$; d.f. = 41.81; $p = 0.022$.

Table 3.28. Wheat yields by plant density

Plant density	Yield (kg/ha)
Good	5,693.87a
Adequate	4,965.44b
Poor	3,679.50c

Note: Different letters indicate significant difference (Duncan (0.05), within-column comparison.

The application of phosphorous also had a positive effect on yield, given that producers who did not apply this nutrient obtained lower yields (Table 3.29).

The average yield was higher in plots that were free of broadleaf weeds, although a significant difference was seen only between fields without weeds and those that were infested to a moderate degree. Yields in lightly infested plots did not differ greatly from yields in either of the other two categories (Table 3.30). With respect to grassy weed infestations, the lowest yields were obtained when grassy weed infestations were severe (Table 3.31).

As noted earlier, yields were highest for producers who used both mechanical and manual weed control, although there is no significant difference between this group of producers and those who do one mechanical or one hand weeding. Yields obtained by producers who did not control weeds, or who controlled weeds only with herbicide, are significantly less than those obtained by the other two groups (Table 3.32).

Table 3.29. Wheat yields by level of phosphorous application

Applied phosphorus	Number of farmers	Yield (kg/ha)
No	29	5,070.86
Yes	56	5,670.25

Note: t = -2.93; d.f. = 83; p = .004.

Table 3.30. Wheat yields in relation to level of broadleaf weed infestation

Infestation level	Yield (kg/ha)
Free	5,650.95a
Light	5,083.33ab
Moderate	4,709.89b

Note: Different letters indicate significant difference (Duncan (0.05), within-column comparison.

Table 3.31. Wheat yields in relation to level of grassy weed infestation

Infestation level	Yield (kg/ha)
Free	5,641.77a
Light	5,480.31a
Moderate	5,435.50a
Severe	4,456.87b

Note: Different letters indicate significant difference (Duncan (0.05), within-column comparison.

Table 3.32. Wheat yields by weed control practice

Weed control	Number of farmers	Yield (kg/ha)
Do not control or use only herbicide	18	5,122.05a
One weeding (manual or mechanical)	42	5,437.12b
Mechanical and manual weeding	25	5,761.32b

Note: Different letters indicate significant difference (Duncan (0.05), within-column comparison.

On the other hand, yields obtained on *ejido* land were less than those obtained on privately owned land and rented land, although there is a significant difference only between the first two groups (Table 3.33). The higher yields achieved by landowners can probably be attributed to that fact that a larger proportion of their land is located on deep clay soils, where the highest yields are obtained. Of course other factors could also be related to the yield difference, such as financial resources. Most *ejidatarios* work with BANRURAL, and this institution has reduced its loans because farmers have adjusted their practices and now produce crops according to specified quotas. Another factor behind yield differences for members of different land tenure classes may be that for *ejidatarios* the availability of machinery is more limited, and thus it is not always possible for them to complete crop operations at the optimal time. The source of this inference is that the distribution of soils on *ejido* land is similar to that on rented land, but renters obtain better yields than *ejidatarios*.

Table 3.33. Wheat yields by land tenure

Tenure	Yield (kg/ha)
Ejido land	5,153.50a
Privately owned land	5,834.71b
Rented land	5,444.71ab

Note: Different letters indicate a significant difference (Duncan (0.05), within-column comparison.

4. Factors Influencing Wheat Yields

Based on the relationships described in the preceding section, a yield function was developed using a stepwise, multiple linear regression. Several agronomic variables, such as broadleaf and grassy weed infestation, type of wheat sown, rates of nitrogen and phosphorous application, planting date, plant density, number of irrigations, salinity problems, and weed control practices, among others, were considered in developing the equation in Table 4.1.

The equation shows that yield diminishes in the presence of broadleaf and grassy weeds. The coefficient obtained coincides with the experience of producers, who consider that grain losses from weed infestations can reach up to 500 kg/ha. On the other hand, weed control through manual weeding, mechanical cultivation, herbicide application, or combinations of these methods has a positive effect on yield. (As mentioned earlier, manual weeding and mechanical cultivation are the most common control practices.) Both weed infestation and weed control variables appear in the model because weed control had been done at the time of the survey, and weeds appearing afterward could also have affected yield.

When plant density is poor, yield is reduced. Farmers generally attempt to obtain good plant populations by sowing large quantities of seed, but agronomic data indicate that a greater quantity of seed may result in less tillering in the wheat plants, as well as a shallow root system. Shallow roots may cause plants to lodge if strong winds occur during irrigation. Both reduced tillering and lodging lead to yield losses.

The plant density factors mentioned previously are confirmed with the coefficient obtained for planting period (Table 4.1). Planting date is important to yield; as indicated earlier, yields are higher when the crop is planted within the optimum period. If wheat is sown at the optimal time, a higher percentage of sprouting occurs, resulting in a greater number of tillers, more grain, and thus higher yields.

Fertilization with phosphorous is important, given that the average dose of 35 kg/ha that farmers applied provided a yield increase of 217 kg/ha. However, the correct application rate must be determined by soil analysis, given that the methodology to determine the quantity of P_2O_5 to be applied is well defined (9 kg of P_2O_5 for each kilogram of P_2O_5 below a critical value of 15).

Table 4.1. Agronomic factors that influence yield

$$\text{YIELD} = \underset{}{5123.03} - \underset{(-2.004)^{**}}{486.89\ \text{WEED}} + \underset{(2.749)^{***}}{575.95\ \text{WEEDCOUNT}} - \underset{(-2.432)^{**}}{1427.29\ \text{DENSITY2}}$$

$$+ \underset{(2.522)^{**}}{464.43\ \text{DTPL2}} + \underset{(2.278)^{**}}{6.49\ \text{P}}$$

R multiple	0.59
R squared	0.35
Adjusted R squared	0.30

Note: Numbers in parentheses are calculated t values. **,*** indicate a significant difference at 0.05 and 0.01, respectively. WEED = broadleaf and grassy weed infestation (free to light=0, moderate to severe=1); WEEDCOUNT = weed control (does not control = 0, controls = 1); DENSITY2 = dummy variable for crop density (good to average=0, poor=1); DTPL2 = date of sowing (other = 0, optimum = 1); and P = total units of phosphorous per hectare.

Producer Characteristics that Explain Agronomic Factors

Among the agronomic factors influencing yield, weed control was the most significant. Mechanical cultivation is the weed control variable that can be explained as a function of farmer characteristics or farmers' cultural practices. Bed planting positively influences the farmer's ability to control weeds mechanically, given that this practice may only be done in bed planting systems (Table 4.2).

Another factor that has a major impact on the use of mechanical cultivation is soil type. In alluvial soils, where traditional planting methods are used more frequently, the probability that a farmer will control weeds mechanically is obviously much lower.

Table 4.2. Farmer characteristics that influence mechanical cultivation

Variable	Description	Coefficient	Wald statistic	Significance
Dependent variable:				
CULTIVATION	Execution of cultivation			
	(0 = no, 1 = yes)			
Independent variables:				
PLANTING	Planting on beds			
	(0 = no, 1 = yes)	3.42	15.15	0.0001
SOIL	Type of soil			
	(0=clay, 1=alluvial)	-1.68	5.39	0.0203
MACHNRY	Machinery			
	(0=owned, 1 = rented)	-2.60	4.26	0.0391
DUMCREBC	Dummy financed by			
	commercial bank			
	(0 = no, 1 = yes)	-1.25	3.09	0.0787
CONSTANT		-1.39	2.82	0.0930
Cases			85	
Log of likelihood function			63.376	
Chi-square statistic for significance of equation			49.216	
Degrees of freedom for Chi-square statistic			4	
Significance of Chi-square statistic			0.0000	
Percentage of cases predicted correctly			83.53	

A similar effect occurs if the farmer has to rent machinery to perform crop operations. Not having one's own machinery reduces the possibility of mechanical cultivation. On the other hand, when the farmer receives credit from private banks, the probability of carrying out mechanical cultivation also diminishes, because these institutions finance a higher percentage of planting in clay soils, where weed problems are less severe and where farmers also weed crops manually. Even though bed planting is more common on this soil type, less mechanical cultivation is done.

5. The Adoption and Diffusion of Bed Planting

Traxler and Byerlee (1993) reported that the practice of planting on beds had increased among farmers since 1980. Farmers who plant on beds were asked a retrospective question during the 1993/94 survey about the number of years that they have planted on beds. The information was used to obtain the following adjusted equation:

[1] $\log((P_t/1.0-P_t)) = -4.0214 + 0.34089t$,

where P_t is the percentage of farmers who planted on beds in the year t, and 1.0 is the supposed limit of adoption (100%).

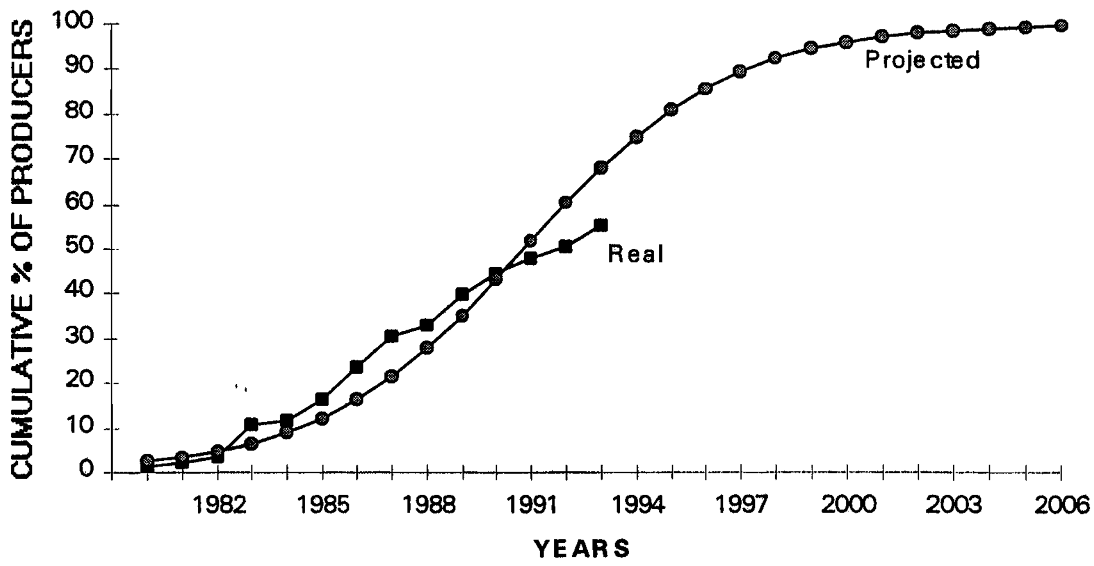

Figure 5.1. Real and projected diffusion of the bed planting method in the Yaqui Valley, Mexico.

It can be seen in Figure 5.1 that levels of adoption in the first years after 1980, especially around 1984, increased rapidly, even exceeding projected levels. Beginning in 1990, growth in adoption fell below the projected level, perhaps because of state cutbacks in technical assistance, which slowed the transfer of technology to farmers. Nevertheless, based on the curve, rising adoption of bed planting is predicted for the coming years, and this adoption may be greater than the projection if diffusion and extension activities are strengthened.

6. Factors Influencing the Adoption of Bed Planting

The earlier analysis found that planting method is related to soil type, machinery ownership, and the type of credit institution serving the producer. The next step is to analyze whether these factors or producer characteristics influence the adoption of bed planting in particular. For this analysis, other variables were included, including technical assistance and land tenure (rental), the former to analyze the effect of technical assistance on the adoption of technology and the latter because it showed a higher frequency with respect to the use of bed planting. One of these factors turned out to be significant (farmers with rented land).

The coefficients obtained from the regression, the results of which are shown in Table 6.1, indicate that two factors are fundamental to the adoption of planting on beds: soil type and machinery ownership.

On clay soils, the probability that wheat is planted in rows on beds increases. This may be related to the fact that clay soils allow better formation and preservation of seed beds than alluvial soils, and that the conservation of irrigation water obtained by using bed planting leads to better water management and control.

Equally important is whether the farmer owns machinery, which also has a positive influence on the farmer's choice of planting method. For bed planting, machinery must be available on time, and proper tools are needed to prepare the land and carry out the practices (e.g., weed control) that are part of the technology.

Another factor that increases the probability of bed planting is whether the farmer rents land. Farmers who rent land seek to reduce costs in fields that do not belong to them. If the farmer rents land for the cycle after wheat, and the subsequent crop in the rotation is soybeans, there is a reduction tillage. For the next crop, the beds only need to be resurfaced and planted again, which implies a reduction in costs from the economic point of view and a reduction in planting steps from the standpoint of soil conservation.

Table 6.1. Factors that influence the adoption of bed planting

Variable	Description	Coefficient	Wald statistic	Significance
Dependent variable:				
PLANTING	Adoption of beds			
	(0=no, 1=yes)			
Independent variables:				
MACHNRY	Machinery			
	(0=own, 1=rented)	-1.63	6.08	0.0137
SOIL	Soil type			
	(0=clay, 1=alluvial)	-1.63	9.34	0.0022
DUMMYREN	Dummy renting			
	farmer (0=no, 1=yes)	0.88	2.76	0.0966
DUMCREUC	Dummy financed by a			
	credit union			
	(0=no, 1=yes)	-1.14	4.38	0.0364
TECNAST	Technical assistance			
	(0=no, 1=yes)	0.72	1.52	0.2180
CONSTANT		0.93	2.80	0.0943
Cases			85	
Log of likelihood function			93.372	
Chi-squared statistic for the significance of the equation			23.509	
Degrees of freedom for the Chi-square statistic			5	
Significance of the Chi-square statistic			0.0003	
Percentage of the cases correctly predicted			68.24	

The probability that a farmer will adopt bed planting is reduced when the financial institution is a credit union, largely because the majority of farmers served by the credit union (53%) grow wheat in alluvial soils.

Technical assistance has a positive, although limited, effect on the adoption of the technology. The contribution of extension is limited because technical assistance is understood or utilized mostly for phytosanitary[4] recommendations. Other types of advice, or the diffusion of technical innovations such as bed planting, are often overlooked.

7. Production Costs

Average production costs per hectare, as well as income from sales and net profit, are presented in Table 7.1 for all farmers surveyed. Under the headings of weed control, fertilizers, and insecticides, the cost of the product and its application are included, in addition to weedings for the first case. For example, the average cost of herbicide (including its application) was MxP$ 44.64 and the cost of weedings was MxP$ 32.29. The miscellaneous costs are an estimation of costs for the sowing permit, soil analysis, irrigation water, agricultural insurance, technical assistance services, interest, taxes, and various other payments. Transportation is indicated in the section corresponding to transport of the harvest for its sale. The price of wheat fluctuated between MxP$ 600 and MxP$ 660/t, depending on the bonuses or discounts applied, while MxP$ 617.45 was the average price received by the producer.

Based on Table 7.1, the greatest share of production costs (around 16%) comes from purchasing fertilizer, followed by land preparation expenses, which represent approximately 14% of production costs. Weed control and seed costs represent 3% and 9%, respectively, of the cost of production. These factors influence planting on beds because the method reduces the use of these inputs, which implies a reduction in production costs. “Miscellaneous costs” include various items, and therefore are not compared.

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[4] These recommendations are made by accredited professionals from the National System of Phytosanitary Accreditation (SENAFI), who work with insect and disease problems in crops (technical assistance and certification).

Table 7.1. Production costs and net profits per hectare for wheat in the Yaqui Valley, 1993-94 (in Mexican pesos/ha)

Variable	Average	Standard deviation	Minimum value	Maximum value	Percent of total costs
Soil preparation	317.36	95.53	146	626	14
Seed	199.21	51.72	105	320	9
Planting	45.00	0.00	45	45	2
Irrigation	104.67	44.45	60	480	4
Canal cleaning	18.98	22.70	0	187	1
Weed control	80.67	108.97	0	414	3
Cultivations	14.68	20.69	0	64	1
Fertilizers	379.45	145.60	92	709	16
Insecticides	0.99	6.76	0	56	0
Miscellaneous	996.00	0.00	996	996	43
Harvest	145.53	8.37	120	170	6
Harvest transport	27.36	3.02	15	35	1
Total cost	2,335.35	217.47	1,861	2,960	100
Yield (kg/ha)	5,465.75	934.13	2,142	7,140	
Income from sales	3,370.46	587.87	1,332	4,497	
Net profit	1,014.91	619.26	-1,076	2,277	

8. Economics of Bed Planting

The bed planting technology began to spread in 1980, when it was presented as an alternative for achieving better weed control, avoiding losses in yield and grain quality, and reducing the application of harmful agrochemicals. Producers currently consider the technology as an alternative that reduces production costs and raises yields, although results from the survey have shown that the differences are not significant. However, by developing a partial budget to compare costs of each technology, it can be seen that planting on beds offers an overall cost advantage of MxP$ 71/ha over planting in corrugations, and an advantage of MxP$ 94 with respect to *melgas*. Table 8.1 presents partial budgets with the labor and input costs for each technology.

Table 8.1. Partial estimate (Mexican pesos/ha) of planting technologies in the Yaqui Valley

	Planting method		
Variable	Beds	Corrugations	*Melgas*
Soil preparation	322	328	290
Seed	178	210	246
Weed control	71	90	95
Cultivation	25	5	0
Fertilizers	359	393	418
Total costs that vary	955	1,026	1,049

Land preparation

Land preparation costs are lowest for *melgas* and increase for bed and corrugation planting because of making the beds. Costs for beds are MxP$ 32 greater than the costs for *melgas*.

Seed

The lower seed rate needed to plant in rows on beds is reflected in lower seed costs. Costs of seed for bed planting are perceptibly lower than for conventional methods; the difference with *melgas* is approximately MxP$ 68 and MxP$ 32 with corrugations.

Weed control

The cost of mechanical weed control is higher for bed planting. Nevertheless, if mechanical weed control is considered along with the other control methods (herbicide application and manual weeding), expenditures on weed control are the same (MXP$ 95) for all three planting technologies, although better weed control is obtained on beds because the control methods can be combined.

Fertilizers

Fertilizer expenditures are also lower with bed planting, because fewer units of nitrogen are applied. The highest fertilizer cost occurs for *melgas* (MxP$ 59/ ha more than for beds), and the cost of corrugations is in between (MxP$ 34 higher than for beds).

However, when total average costs, income from sales, and net profits are compared, significant differences are exhibited between planting methods, as seen in Table 8.2.

Table 8.2. Average costs, income, and profits (Mexican pesos/ha) by planting method

	Planting method		
Variable	**Beds**	**Corrugations**	***Melgas***
Total costs	2,294.02	2,372.01	2,403.48
Gross income from sales	3,471.39	3,425.91	3,026.21
Net profit	1,170.02	1,005.65	622.73

Costs

Although there is not a notable difference between the planting methods, the lowest total costs are incurred with bed planting. Costs are about MxP$ 109/ha lower than for *melgas* and about MxP$ 78/ha for corrugations, owing to the lower quantity of seed and nitrogen used.

Gross income from sales

The greatest income was received by farmers who sowed in rows on beds. The higher yields obtained through this technology have a positive effect on income compared to the conventional sowing methods. This difference is most marked between beds and *melgas* (income is about 15% higher).

Net profit

The combination of lower costs and higher yields results in a greater net profit for bed planting than for corrugations (14% higher) and *melgas* (53% higher).

When the cost-benefit analysis is broken down by soil type (Table 8.3), bed planting is as profitable on clay soils as on alluvial soils. In clay soils, the net profit obtained using beds was higher than for corrugations and *melgas* (MxP$ 136/ha and MxP$ 655/ ha, respectively). On the other hand, in alluvial soils, where a higher proportion of farmers plant on *melgas*, planting on beds was more profitable than corrugations or *melgas* (MxP$ 73/ha and MxP$ 376/ha, respectively).

Table 8.3. Net income (Mexican pesos/ha) by soil type and planting method

	Net profit	
Planting method	**Clay soils**	**Alluvial soils**
Beds	1,216.45	1,012.15
Corrugations	1,080.85	938.79
Melgas	561.28	635.89

9. Summary and Conclusions

Bed planting presents several advantages over conventional planting methods, and these advantages are most pronounced in comparison with planting on *melgas*. The potential of bed planting technology can be seen from three viewpoints: increased productivity, greater resource conservation, and profitability.

Productivity

We have seen that the most significant factors affecting wheat yields in the Yaqui Valley are planting date, phosphorous application, plant density, and weed infestation and control.

Although the optimal planting period is well defined, whether farmers can actually plant at that time depends on weather and the availability of irrigation water. Nevertheless, farmers who planted within the optimal period achieved the best yields.

In general, proper fertilizer application rates can be determined by soil analysis. Survey data indicate that phosphorous applications have a positive effect on yield, but only two-thirds of the farmers applied phosphorous, and only 25% reported doing a soil analysis in the 1993/94 wheat cycle. Nitrogen application did not have a strong effect on yield.

Farmers who planted in beds applied a larger amount of phosphorous, although the difference was not significant. Nitrogen application levels were generally lower (though not significantly) with bed planting, although nitrogen levels are generally high for all planting methods. The idea that greater quantities of fertilizer will result in higher yields leads to excessive nutrient applications. As results of this survey have shown, yields did not vary significantly among producers who had increased the amount of fertilizer, maintained a constant level, or decreased application levels over the last five years.

Farmers in the Yaqui Valley prefer using liquid fertilizer because the management of solid fertilizers such as urea, triple superphosphate, and diamonnium phosphate requires handling higher volumes of inputs, as well as combating problems of poor quality caused by excessive compaction. This increases the time and labor expenditure, which increases production costs.

A good plant population can be obtained by using lower seed rates than those presently used by producers. The method of sowing in rows on beds uses less seed than conventional methods. Although the difference is only significant between beds and *melgas*, even the smaller difference between beds and corrugations clearly shows the potential of the bed planting method. It should be pointed out that farmers, in general, use higher seed rates because they wish to reduce weed competition and obtain better wheat yields, or because they are required to do so for agricultural insurance because of a late planting date.

Farmers who planted on beds had a higher proportion of plots with a good population density.

Mechanical and manual weeding together substantially reduce the risks caused by weeds. When no weed control is done, severe infestations significantly reduce yields.

The bed planting technology allows better weed control (both manual and mechanical). However, a small proportion of farmers who planted in beds reported severe weed problems. There are certain restrictions to the efficient control of weeds, including the adaptations that farmers make to the recommended form of planting on beds, such as decreasing the distance between beds or increasing the number of rows on a bed. Both modifications prevent implements such as a mechanical cultivator from moving between the rows.

The incidence of the factors described above among farmers who planted on beds shows the advantages of the method, which resulted in a better yield per hectare than the technologies of planting on *melgas* and corrugations. The difference, however, is only significant between beds and *melgas*.

Resource Conservation

With regard to resource conservation, we know that beds are used for planting wheat primarily in clay soils, which is partly related to the physical characteristics of these soils. Unlike alluvial soils, in which the seed bed "falls" with irrigation, clay soils make it easier to form and preserve beds.

The available technical information indicates that clay soils require a greater quantity of irrigation water compared to alluvial soils. Nevertheless, significantly fewer irrigations were applied to land planted with beds than to land planted with traditional methods in clay soils. The same number of irrigations was done for beds in clay soils as in alluvial soils, which indicates that bed planting conserves water and improves irrigation efficiency in clay soils.

Another resource conservation issue is related to agrochemicals. In the Yaqui Valley, as in other areas of commercial agriculture in Mexico, the indiscriminate use of agrochemicals is considered a public health problem. As the costs of agrochemicals in general, and of herbicides in particular, have notably increased in Mexico over the past few years, farmers have increasingly considered bed planting as an alternative that permits them to weed their crops mechanically and manually, which costs less than chemical products and their application. In this way, Yaqui Valley farmers are approaching a more rational use of agrochemicals.

The technology of planting in rows on beds has other resource conservation aspects which have not yet been studied in detail, such as the profitability of using the bed for the following crop (generally soybeans). In this case, the farmer eliminates some operations, such as harrowing to plant on beds. After the wheat harvest, the bed only has to be resurfaced and to be used for a new crop.

A final resource conservation issue to consider is the management of residues from the wheat harvest, which can extend into May, when soybeans are sown. As noted earlier, farmers prefer to burn the wheat stubble. Technical alternatives for the management of residues must be diffused if they already have been generated or researched further.

Profitability

Production costs are lowest with bed planting because of savings from inputs such as seed and fertilizer, which together represent 25% of the general wheat production costs for survey farmers. Bed planting permits smaller quantities of inputs to be applied and the savings on these outweighs the higher land preparation costs for forming the beds. Although it might seem that there would be an increase in the use of machinery and manual labor for weed control on beds, the costs associated with these control methods are actually equal to the costs of controlling weeds in conventional planting.

Bed planting is more common on clay soils, and it is here that the technology has the greatest profitability over corrugations and *melgas*. Nevertheless, in alluvial soils, planting on beds still presents attractive gains for producers. In both cases, the difference in net productivity is very marked with respect to *melgas*. The evidence shows that the technology is generally suitable for the cultivation zone. The current economic situation in Mexico makes this technology an attractive option for producers to increase income, reduced costs, and obtain better yields.

Adoption of the Technology

Once the productivity gains, resource conservation potential, and economics of the planting method are analyzed, it is necessary to analyze the conditions or characteristics of the producer that limit or influence adoption of the technology.

One of the most important farmer characteristics that affects the decision to plant on beds is the type of soil where the farmer produces wheat. Those who farm clay soils have a higher probability of planting on beds.

Possession of machinery also influences the bed planting decision, because the method cannot be implemented without proper machinery. Along with the public sector's contribution to developing the technology, the private sector's contribution is also important for the design and manufacture of proper tools that producers can afford.

When producers obtained credit via a credit union, the effect on adoption was negative. This effect is related to the tendency of these institutions to finance a greater share of agriculture on alluvial soils, where beds are used less frequently.

Farmers renting land, who now represent a little more than 40% of the sample, have a greater probability of adopting bed planting, perhaps because the technology reduces costs and also reduces the tillage requirements for crops in rotation. Renters generally seek to avoid investments or improvements in land they do not own.

In spite of the fact that technical assistance has a positive effect on the adoption of bed planting, it was not significant in the model. This result probably reflects the effects of new policies in the agrarian sector, particularly the withdrawal of the Ministry of Agriculture and Water Resources (SARH) from providing technical assistance. Beginning in 1990, the Federal Government created private offices to provide this service, charging for it as any other professional service. The area receiving technical assistance declined because farmers were reluctant to pay for this service, above all if they were new landowners. Technical assistance is currently viewed by producers as largely consisting of phytosanitary advice. Because agricultural insurance agencies require farmers to have written recommendations for their fields from an authorized technical expert, the majority of producers state that they have had technical assistance.

This situation is weakening the mechanism established in earlier years to communicate research results through extension services to farmers, and it is reflected in the technology adoption curve for bed planting. From 1980 to 1989, a considerable expansion of technology is observed, but since 1990 the cumulative percentage of adopters has fallen below the projected estimate.

Given these changes in policy, adoption of the bed planting technology, rather than declining in importance, has the potential to continue growing because of its potential profitability, its potential for conserving resources. including water, and the potentially beneficial environmental effects of reduced use of agrochemicals.

Nevertheless, the involvement of technical assistance agents in the field is important for extending bed planting and other research innovations to farmers. There must be a means of providing farmers' feedback on the technology to researchers – both information on adoption and on farmers' adaptations to the technology. This may be achieved to a large extent by re-establishing the link between farmers and research centers through mechanisms designed to strengthen the activities of technical assistance programs. These mechanisms may be designed to insure both the payment of extension service providers as well as the access of the majority of producers to this type of service. This could be done through economic support on the part of producers and of different levels of the government, because commercial agriculture in the zone has a need for an extension system. With such support, bed planting is much more likely to achieve its potential in the region.

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11. Glossary

a chorrillo	continuous seeding
ahijamiento	tillering
al voleo	broadcast
aluvión	alluvial
amacollamiento	sprouting
barbecho	plowing
barrial	clay
cultivadora	cultivator
cuotas	fees
cuotas	loans
curvas de nivel	melgas on the contour
deshierbes manuales	hand weeding
escardas	mechanical cultivations
espigas	shoots (spikes)
fondo de aseguramiento	agricultural insurance fund
fondo de surco	furrow
hilera	row
hoja ancha	broadleaf weed
hoja angosta	grassy weed
lomo de surco	bed
maleza	weed
melgas	*melgas*
pequeña propiedad	privately owned land
pequeña propietarios	owners of private (not communal) land
rastra	harrow
rastrojo	stubble
rentabilidad	profitability
sembradora	seeder
surco	bed
surcos de corrugaciones	shallow furrow
tablón	leveling with pieces of wood
trigo duro	durum wheat
trigo harinero	bread wheat

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