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Harvest-Expedition on Protected Cultivation: characterization and prospective study of the challenges and solutions associated with the protected cultivation of vegetable crops

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ABSTRACT

Farmers and the rural extension service in Planaltina, in the Federal District, an important pole of tomato and sweet pepper production in the Brazilian Midwest region, have been observing decreases in yield in protected cultivation lately. Yields are getting back to those registered in initial years of the system's implementation in the region. Besides, prices paid to farmers dropped due to the retreat in fruit and vegetable consumption by Brazilians registered since 2015, triggering a crisis in the region. The so-called "Harvest-Expedition on Protected Cultivation" brought together Embrapa (Brazilian Agricultural Research Corporation), Emater-DF (Federal District Agency for Technical Assistance and Rural Extension) and SEAGRI-DF (State Secretariat for Agriculture, Food Supply, and Rural Development) to contribute on identifying and possibly finding solutions to the bottlenecks related to the technological and behavioral challenges likely to be causing yield drops and, consequently, reductions in farmers' incomes. We carried out semi-structured interviews in April 2017 with all 127 producers who adopt protected cultivation in the region to profile them, as well as to characterize their properties, protected cultivation structures, and crop management, especially for tomato and sweet pepper. Agriculture is eminently family-based in the region and pressure over yield comes mainly from the continuous increase in the incidence of pests and diseases, strengthened by the low level of implementation of good agricultural and management practices. Despite the current adverse scenario, collaborative and multidisciplinary work in the region, bringing together organized farmers and the institutions involved in this survey, could revert the situation.

Keywords: diagnosis, tomato, sweet pepper, management, scenarios.

RESUMO

Expedição-Safra Cultivo Protegido: caracterização e estudo prospectivo dos desafios e soluções associados ao cultivo protegido de hortaliças

Produtores e extensionistas rurais de Planaltina-DF, um dos principais polos de produção de tomate e pimentão da região Centro-Oeste, relataram redução de produtividade em cultivo protegido, com os níveis regredindo à produtividade alcançada nos anos iniciais de implantação desse sistema na região. Além disso, o recuo do consumo de frutas e hortaliças pelos brasileiros desde 2015 fez os preços pagos ao produtor despencarem, desencadeando uma crise na região. O diagnóstico denominado "Expedição-Safra Cultivo Protegido" reuniu Embrapa, Emater-DF e Seagri-DF com a finalidade de contribuir na identificação e eventual solução dos gargalos de adoção tecnológica e de comportamentos associados a perdas de produtividade e, consequentemente, possível redução de renda dos produtores. Em abril de 2017, foram realizadas entrevistas semiestruturadas com todos os 127 produtores que adotam o cultivo protegido na região, caracterizando os produtores, as propriedades, as estruturas de cultivo protegido e o manejo das culturas, em especial tomate e pimentão. Constatou-se uma agricultura de base principalmente familiar e que o aumento da incidência de pragas e doenças ao longo dos anos, agravado pela baixa adoção de Boas Práticas Agrícolas e de Gestão, foi o principal responsável pela redução da produtividade. Esse cenário negativo pode ser alterado por um trabalho conjunto e multidisciplinar na região, com a participação dos produtores organizados e das instituições envolvidas no levantamento.

Palavras-chave: diagnóstico, tomate, pimentão, manejo, cenários.

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Harvest-Expedition on Protected Cultivation

Embrapa Hortaliças (The National Center for Research on Vegetable Crops, Brazilian Agricultural Research Corporation), the Federal District Agency for Technical Assistance and Rural Extension (Emater-DF) and State Secretariat of Agriculture, Food Supply and Rural Development (SEAGRI-DF) carried out an on-farm survey named "Harvest-Expedition on Protected Cultivation" in 2017. The Expedition was meant to contribute to the identification and eventual solution of technological and behavioral bottlenecks associated with yield drops in the protected cultivation of vegetables, which has been jeopardizing farmers' incomes.

Although figures point to increases in the vegetable supply in the 2016/2017 season in Brazil (CEPEA, 2017; CEASA, 2018), the rural extension service and farmers have been reporting decreases in the productivity of vegetables grown in protected cultivation in the region of Planaltina, in the Federal District. Yields are getting back to levels similar to those observed in the initial years of the implementation of greenhouses in the region. Additionally, Brazilians have been reducing the consumption of fruits and vegetables since 2015, when the current economic crisis exploded. Yield drops and the reduced demand impacted the profitability of vegetable producers

in 2017. For example, the table tomato container sold directly by farmers had a 73% reduction in price in the 2016/2017 harvest (CEPEA, 2017).

In this context, the main objectives of the Harvest-Expedition on Protected Cultivation were:

-To portray farmers' profile and to characterize the production of vegetables in protected cultivation in the region of Planaltina-DF;

-To identify the challenges faced by the protected cultivation of vegetables in the region;

-To analyze the adoption of technologies by farmers;

-To survey the demands and opportunities to technical research, to strengthen the effectiveness of technical assistance and rural extension services, and to leverage the actions of institutions in charge of developing public policies.

Interviews with farmers

The survey had a quantitative-qualitative methodological approach. We carried out semi-structured interviews with vegetable growers from the administrative region of Planaltina, located in the green belt of Brasília, the federal capital. Planaltina concentrates four rural areas, namely Taquara, Pipiripau, Rio Preto and Tabatinga; occupies about 30% of the DF rural area (Caliman, 2013); and is home for a significant number of small, medium and large farmers. It contributed to the expansion of protected cultivation in the DF, which began in the 1990s, with the opening of new export markets, mainly to the north and northeast regions of Brazil (Junqueira, 2002). Currently, it concentrates a major part of DF's protected cultivation structures. Therefore, Planaltina has an expressive volume of production and representative productivity indexes.

The semi-structured interview was used because it allows collecting personal, social and situational motivation, subjective opinions and perceptions, as well as objective data. A multidisciplinary team of researchers, analysts and extension agents from the three institutions involved in the work planned the interviews and elaborated the questionnaires. Questionnaires had the following blocks: a) identification of the property and farmer sociodemographic information; b) characterization of the protected cultivation structures (plastic/screen/tunnel); c) characterization of crop management; d) characterization of the structure use (crops); e) characterization of plant health management; f) post-harvest and commercialization, and; g) personal, social and situational motivation for adopting protected cultivation. Qualitative responses were analyzed and grouped by similarity. All data (qualitative and quantitative) were plotted in graphs.

We interviewed a representative of each production unit where there were protected crop structures in the region in a census-type survey, in total 127 interviews. These production units corresponded together to approximately 75 ha and 1,698 cultivation structures, including plastic and wirehouses and tunnels.

The diagnosis

Who are the farmers who grow vegetables in protected cultivation?

Although farmers growing vegetables in protected cultivation in Planaltina had 49 years old on average, the largest group (28%) ranges from 51 to 60 years old. On average, farmers have ten years of experience in protected cultivation. These figures, to a certain extent, support Buainain *et al*. (2014), who states there is a process of rural aging in Brazil. Nevertheless, more than half of the farmers we interviewed are below 50 years, and nearly a quarter, below 40 years old. Although protected cultivation in the region began in the 1990s, it was only in the following decade that it gained momentum. In 2001, the Oziel Alves III Settlement was established, with 170 properties (Caliman, 2013) and, in 2003, the Fazenda Larga Settlement, with 77 properties. In both settlements, several producers adopted the protected cultivation (Emater-DF, 2010). This new range of farmers may have reduced the average time of experience with protected cultivation in the region. It is necessary to follow more closely the evolution of rural occupation in the region from this survey to conclude if trends are for the increase or decrease in the number of properties, aging of farmers or entry of new farmers into the business.

Farmers have a very diverse background. Only 13.5% were born in the Federal District. Farmers come mainly from the neighbor states of Goiás (20.5%) and Minas Gerais (16.6%), and of Ceará (12.7%), in the Northeast region. Farmers' level of education is as follows: 39.4 and 9% have not completed and completed the elementary school, respectively; 12.6 and 24.4% have not completed and completed the high school, respectively; and just over 10% of the farmers have higher education. The level of education correlates with the ability to absorb knowledge (Buainain, 2014). The high percentage of farmers with low schooling in Planaltina may be threatening knowledge advance, technology adoption and innovation implementation in the region, as well as improvements in business management.

Labor is predominantly family-run in the protected cultivation in Planaltina. About 270 people or 56% of the workers are family members, while 44% (209 people) were hired, in the last harvest (except day laborers). In periods of intense labor demand, farmers hired day laborers (164 days/year, on average).

Why the protected cultivation?

A relevant contribution of our work was the search for the reasons why farmers in the region adhered so unanimously to the protected cultivation. For this end, we asked them to name the advantages and disadvantages of the system. Half of the farmers claimed that the main advantage is the possibility of growing crops regularly during the rainy season when open field crops suffer intense disease pressure due to excessive rainfall. Farmers also indicated as advantages the better quality of the products coming from protected cultivation (34%) and more comfortable work conditions (24%) due to the greenhouse protection from both sun and rain. Protection against challenging weather is an essential factor in lessening the difficulties of

the work in farmers' point of view. The physical protection structures given against pests and diseases, and the reduction in the use of agrochemicals were advantages mentioned by 18 and 12% of the farmers, respectively. A smaller share of farmers, 8 and 6%, respectively included as advantages the higher price paid by the market and the higher yields when compared to open field crops, while 6% of farmers recalled the economy in fertilizers and reduction in labor.

As for the disadvantages of protected cultivation, 29% of farmers indicated the high costs of maintenance and implementation of the protected cultivation structure. Plastic covers very often tear, mainly due to wind and whirlpools. The initial investment to implement the greenhouse is high, which explains its use to grow high added value products. Nevertheless, the market does not always pay such value. In 2017 for example, prices paid to farmers for tomato and sweet pepper containers were below the expected value during most of the year. About 12% of the farmers do not consider there are disadvantages in protected cultivation and 10% complained about the high temperatures inside the greenhouses.

How large are the properties?

The properties making use of protected cultivation in Planaltina are predominantly small by the regional standards: 77% have up to 20 ha, of which 39% have up to 5 ha. The effective area under protected cultivation is 9.2% of the total area on average. Farmers predominantly grow the crops directly in the soil (94%); only 6% use semi-hydroponics or hydroponics in the region. In settlement Fazenda Larga, one of the targets of this survey, lots are 2 ha large on average, and about 82% have a protected cultivation area of up to 1 ha, i.e., the average productive area under protected cultivation is approximately 50% of the property.

Which are the main characteristics of the protected cultivation structures?

Almost all structures in the region, 97%, are plastic houses, widely used to grow tomatoes and sweet pepper. Screen houses are much less frequent, about 15%. Historically, the region started using greenhouses to grow tomatoes and sweet pepper from 1990, according to reports from Emater-DF extension agents. This scenario persists to date. The area occupied by plastic houses reaches almost 80% of the total area under protected cultivation in the farms, with screen houses and tunnel occupying the remaining 20%.

About 46% of the plastic houses have ceiling height (from the ground to the lower part of the cover arc) between 2.1 and 2.5 m. Higher structures (between 2.6 and 3.0 m) and lower (between 1.5 2.0 m) occurred in 26 and 18% of the surveyed areas, respectively. The recommended standard for ceiling height to provide thermal comfort to plants and workers is over 3.0 m. Presently, only 10% of the structures are that high. The cost of higher plastic houses substantially reduces their frequency in the region. Greenhouses with antechamber; airflow; radiation, temperature, and humidity assessment; nebulization; shading; and light diffusion are also rare. These technologies are associated with pest and disease control and higher fertilizer and nutrient use efficiency by plants. However, they also incur in higher implementation costs.

The plastic most regularly used in plastic houses is 75 µm-thick. It appears in 33 and 23% of the plastic houses where tomato and sweet pepper are grown, respectively. Although the recommendation points to 150 µm-thick plastic, the prevalence of the former is again due to the cost: the 75 µm-thick plastic is substantially cheaper. Approximately 53% of the plastic houses are covered with one-piece plastic, and more than 90% have wooden structures with sides closed by insect-proof screens (67%).

Which crops farmers predominantly grow in protected cultivation in the region?

Tomatoes and sweet peppers occupy 37.6 and 32.2% of the protected cultivation structures respectively, and 61 and 44% of the farmers. Nearly 10% of the farmers also grow cucumber simultaneously. Leafy vegetables are also present, but they are not very expressive: lettuce, rocket, and chives + coriander appeared in 4% of the structures. Other vegetables, especially snow peas, bush beans, and zucchini, are complementary and therefore grown after tomato or sweet pepper, to take advantage of the residual fertilization or to try to reduce pest and disease incidence in the next cycle. Besides vegetable production, some structures are used to produce ornamental plants and fruit tree seedlings too. At the time of the survey, 14% of the structures were empty. According to farmers, it reflected the financial difficulties they are going through.

How farmers manage tomato and sweet pepper in protected cultivation?

Some crop management practices will be approached jointly for tomato and sweet pepper, to allow comparison between practices and optimization of the information.

The use of mulching is one of such cases. Cost is decisive to adopt it, as also observed for previous aspects. While most tomato producers (65%) abandoned the use of mulching, in sweet pepper, a high percentage of farmers (87%) continue to use it. The practice of covering the soil meets agronomic recommendations since it significantly increases water use efficiency (Souza *et al*., 2011).

Soil chemical analysis also draws attention: although 70% of the farmers carried it out, the periodicity is hugely variable: 40% of the farmers who do the soil analysis perform it annually; 13%, whenever planting a new crop, and; 24%, sporadically, with variations of up to four years. Unlike the soil analysis, the analysis of the soil electrical conductivity is much more occasional. Only 21% of the farmers carried it out, a quite negative aspect as far as the management of protected cultivation structures is considered. The assessment of the soil conductivity makes it possible to monitor cation exchange; calcium, magnesium, and salts content in the soil solution; organic matter content, and other aspects. The monitoring of soil

conductivity and pH allows farmers to keep an adequate balance of fertigation (Silva Junior *et al*., 2016).

Organic fertilization is widely used to grow both tomato and pepper, 94 and 95% of the farmers use it, respectively, and poultry litter is the leading organic fertilizer (38 and 27%, in tomato and pepper, respectively), followed by castor cake, and soil conditioners. Only 9 and 1% of tomato and pepper producers, respectively, use composts, possibly due to difficulties in purchasing or producing it on-farm, since it is time- and labor-demanding. Few farmers use biofertilizers (30%) and green manures (37%).

Protected cultivation makes intensive use of the soil. Although we noticed the use of some conservation practices, such as organic fertilization, no-tillage systems are nearly absent in the production of vegetables in protected cultivation in the region. On the other hand, 77% of the farmers use crop rotation. Results point to much room to advance in the implementation of soil conservation practices in protected cultivation, essential for keeping the fertility and balance of the soil.

All interviewed farmers use drip irrigation. However, 90% do not adopt any parameter to assess water demand in tomato or sweet pepper. Just over 23% of the farmers do the "hand test", which consists of tightening a small amount of soil in hand and feel the humidity of the sample through the touch. If the soil is moldable to the hand, there is water available for plants. Approximately 5 and 6% of the farmers assess the water demand using the conventional tensiometer and the Irrigas®, respectively.

We observed that 84% of the tomato growers use single row planting, with an equivalent number of drip lines per plant: 49% use one drip line per row and, 51%, two drip lines. In sweet pepper, the scenario is naturally different: 48% of the farmers adopt single rows and 52%, double rows. However, 70% of the pepper producers use only one drip line per planting row.

Characteristics of tomato and sweet pepper crops in protected cultivation in Planaltina

Tomato

The area used for tomato production in protected cultivation was 36.43 ha in April 2017 in Planaltina. Half of the farmers grow only one crop per year, and all farmers use hybrid cultivars. The leading hybrids were Predador, BS 04, Timex, Jupiter, BS 12, Ellen, and Dominator (Figure 1). The numerous hybrids mentioned by farmers showed that there is a reasonable level of cultivar diversification in the region.

Most farmers (47%) harvested between 100 and 200 20kg-crates per 350 m^2 plastic house, while 17% of them reached yields of more than 200 crates (Figure 2). It is noteworthy that 23% did not know their crop productivity. The expected yield when using the inputs and services recommended in the cost of production table (Emater-DF, 2017a) is 250 20kg-crates per plastic house, that is, 140 t ha^{-1}. We realized that most of the Planaltina farmers could reach higher yields. Probably, the limited productivity reported in this survey is related to the low investment farmers did in their crops. They saw no advantages in investing in inputs and improvements to raise yields, as the economic crisis of recent years has resulted in price reduction.

After a period of turbulence between 2015 and 2016, the sales margin (difference between prices paid to farmers and prices paid by consumers) of table tomatoes became minimal and retailers put pressure on farmers to reduce their prices to lower financial risks and prevent the retailing business from being threatened by large price swings (Carvalho, 2018). From February 2016 to December 2017, the difference between prices paid to farmers and received from consumers has increased by approximately 100%. The new market-set left farmers with negligible profitability. In December 2017, farmers received on average R$ 29.40 or US$ 9.00 for the 20kg-crate, with an average cost of production of R$ 28.55 per crate (US$ 8.75) (CEPEA, 2017; Banco Central do Brasil, 2018).

Sweet pepper

The total area planted with sweet pepper in protected cultivation was 19.04 ha in April 2017, according to farmers, and 88% of the farmers carry

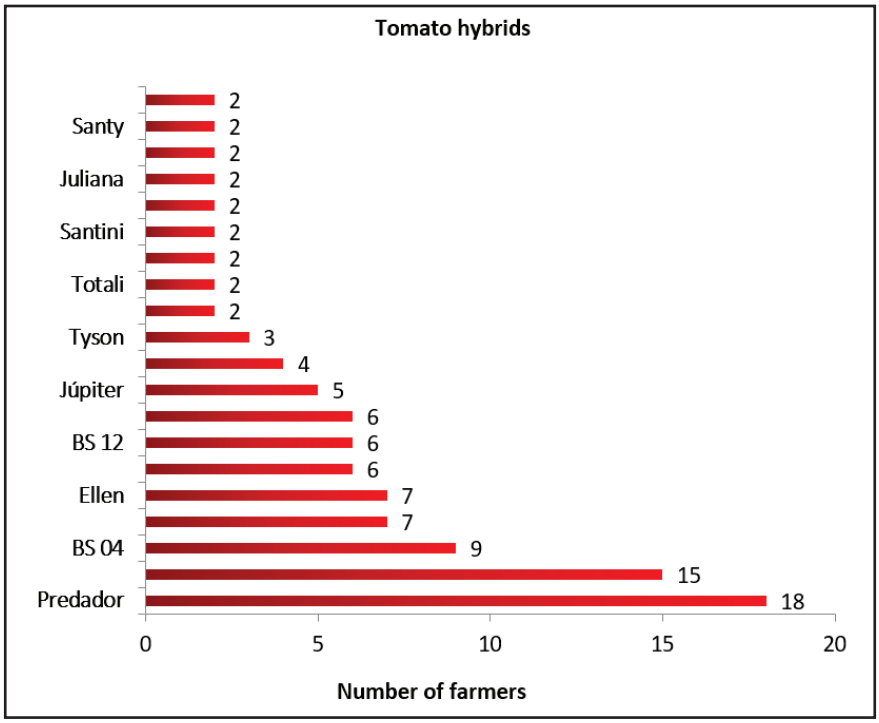

Figure 1. The numerous hybrids mentioned by farmers showed that there is a reasonable level of cultivar diversification in the region. Brasilia, Embrapa Hortaliças, 2018.

out only one crop per year. Margarita, Rubia, and Pappone were the leading hybrids (Figure 3).

Most farmers produced between 201 and 400 (33%) and between 400 to 600 (26%) 10kg-crates per 350 m² plastic house (Figure 4). The expected yield using the recommendations of Emater-DF (2017) would be at least 600 sweet pepper crates per plastic house, the equivalent of approximately 17 t ha^{-1}. Only 5% of the farmers in Planaltina reached this standard. About 26% of the farmers did not know their yields.

Sweet pepper prices fell sharply in 2017. At the wholesale market (CEASA) of Brasília, sweet pepper prices went from R$ 2.98 per kg (US$ 0.82) in June 2016 to R$ 1.63 (US$ 0.52) in February of 2017 (Banco Central do Brazil, 2018; CONAB, 2018). The fall in prices hampered farmers' investment in their crops, as reported by some producers in the interviews. Some farmers, mainly in the settlements, reported that they stopped repairing the plastics from the plastic houses because they could not afford the costs due to the low prices received when trading their products, below production costs.

Plant health in the protected cultivation crops

Growing vegetables is already a matter by itself of handling plants relatively more susceptible to pests and diseases. When we found out that farmers in this survey did not use a few good agricultural practices, we realized that there were many aspects to be improved concerning plant health. About 37% of farmers still plant new crops next to old crops, getting to senescence, which may lead to an increase in pest incidence in the new crop. It occurred both inside the same plastic house, as in neighbor protected cultivation structures, with joint irrigation water runoff and shared use of implements, machinery, and tools without proper sanitation. Only 48% of the farmers use windbreaks, which are known to be efficient in containing pest migration.

The two-spotted spider mite, *Tetranychus urticae*, mentioned by 31% of the farmers, led the list of pests requiring the highest number of management practices in 2017, repeating the previous two years. Farmers also highlighted the tomato small-borer, *Neuleocinodes elegantalis*, cited in 27% of the interviews, and virus vectors [whitefly (*Bemisia tabaci* biotype B; thrips (*Thrip s*sp.); and aphids (*Mysus* sp.)], cited in 17% of the interviews. The tomato leafminer (*Tuta absoluta*) demanded control practices of 11% of the farmers, followed by the vegetable leafminer (*Liriomyza sativae*), 3% of the farmers. The tomato powdery mildium (*Oidium lycopersici*) was the most challenging disease, mentioned by 5% of the farmers.

Most farmers (65%) did not observe pests in 2017 that had not been observed in previous seasons. Nevertheless, pests such as the fly, the vegetable leafminer, and the two-spotted spider mite appeared for the first time to 3% of the farmers each, followed by defoliating caterpillars, mildew, and the white rust, reported by 2% of the farmers each. A few farmers, 13%, had difficulties to control the Diptera *Dasineura* sp., which attacks sweet pepper flowers and until recently had not been observed.

Farmers also mentioned secondary pests such as the mealy bug (*Pseudococcus maritimus*) and the diamondback moth (*Plutella xylostella*), as well as some diseases such as anthracnose (*Colletotrichum phomoides*), the bacterial wilt (*Ralstonia solanacearum)*, early blight (*Alternaria solani*), the coriander leaf blight (*Alternaria dauci*) and Tospoviruses. Together, the secondary pests and diseases indicated here were reported by 9% of farmers. Besides, 4% of farmers recalled weed interference: nutgrass (*Cyperus rotundus*), Benghal dayflower (*Commelina benghalensis*), and sourgrass (*Digitaria insularis*), while another 3% of farmers mentioned nematodes (*Meloidogyne* spp).

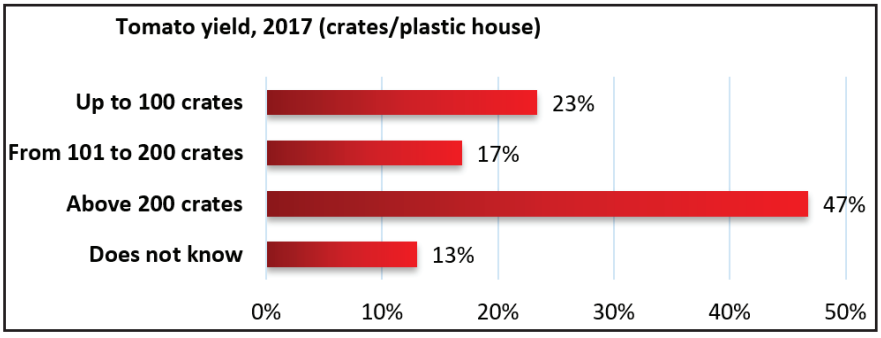

Figure 2. Tomato yield (20kg-crate in 350 m² standard plastic houses) reached by farmers in protected cultivation in Planaltina, season 2017. Brasília, Embrapa Hortaliças, 2018.

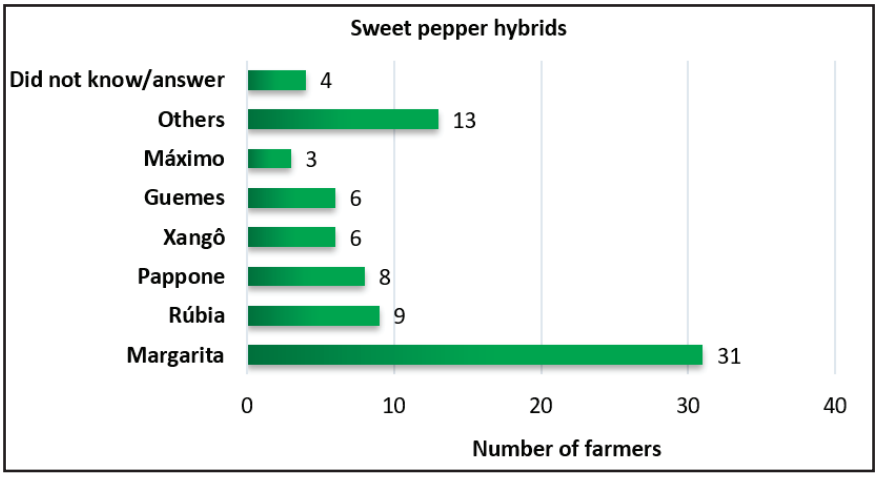

Figure 3. Sweet pepper hybrids grown in protected cultivation in Planaltina. Brasília, Embrapa Hortaliças, 2018.

The Ministry of Agriculture, Livestock and Food Supply published the Guidelines for Sweet Pepper Integrated Production (PIP) in 2018 to assist sweet pepper producers. The PIP resulted from research carried out at Embrapa Hortaliças. Information, demonstration, and capacity strengthening actions are planned for the coming months for producers and extension agents so that the sweet pepper integrated production can be implemented the soonest. Pest and disease management is one of the main problems PIP addresses, once most farmers carry it out improperly (Pinheiro *et al*., 2016). Nematodes also deserve attention in sweet pepper production. Their wide range of hosts, mainly among Solanaceae crops such as tomato, the scarlet eggplant, eggplant, chili pepper, and potato, makes their management even more difficult in the context of PIP.

Farmers combined several strategies to decide on the use of pesticides: 63% of the farmers mentioned the calendar-based application, as well as pesticide spraying following Emater recommendations (39%), based on their own experience (20%), and by recommendation of agricultural supply stores (14%). Several farmers preferred not to run into risks of high losses due to the high investment protected cultivation demands. Therefore, they used pesticides as a major pest and disease control method, even without any level of economic damage. The triggering factor to use pesticides for 72% of the farmers is simply the presence of the pest or the observation of disease symptoms in the crop.

Post-harvest and commercialization

Most farmers (51%) do not have adequate facilities, understood as a covered place with a cemented or cemented-like floor, for post-harvest activities such as grading and storage until transportation to the market. Farmers graded their products under trees or within the protected cultivation structure itself. About 91% of the sweet pepper and tomato producers graded the products on-farm, while the remaining farmers alleged they did not have the time or the laborers to do it. Farmers grade their products because they receive higher prices than for ungraded and many markets demand it.

The points of sale are variable, and we observed that the same farmer very often used more than one point, depending on the convenience of the moment. Main destinations were: trade agents or middlemen (58%), cooperatives (40%), fairs (40%), and CEASA, the wholesale market (32%). Currently, few farmers (2%) sell to government programs such as the Food Acquisition Program (PAA), the National School Feeding Program (PNAE) or the Agricultural Production Acquisition Program (PAPA-DF).

Sources of information used by the farmers

The identification of the sources most frequently used by the farmers to search for agricultural information is a relevant contribution from this set of interviews to be used by research institutes and extension services when choosing the channels to communicate with their beneficiaries. Agricultural supply stores (70.1%) and Emater (68.5%) were the first sources of information recalled by farmers. The broad scope underlines the strength of commercial agents in the productive chain and the capillarity of their presence, enhancing their potential as partners for communicating advances in science and innovation. The farmers also sought information on events such as field days, talks, and fairs (48%); in the TV program Globo Rural (45.7%); and on the internet, especially in Google (44.9%). Neighboring farmers, magazines, and Embrapa were cited by 19.7, 16.5 and 16.5% of the farmers, respectively. The social media What's App also became a source of agricultural information lately. Approximately 15% of farmers said they solve technical issues using the app, by exchanging messages within fellow farmers' discussion groups. Less than 1% of the farmers looked for technical information in books.

Technological audiovisual resources positively influence the teaching-learning process in children and also in teenagers and adults (Pazzini, 2013). Videos with language suitable to farmers tend to be better accepted by them, mainly due to the still low schooling in the rural area and the high illiteracy rate. In Brazil, 29.8% of the people managing farms are illiterate. In the region surveyed here, almost 50% of farmers did not reach the high school. Printed and digital media and TV and radio programs are the main channels Embrapa uses to disseminate scientific research. However, few farmers seem to have had access to this information, except for insertions in the TV program Globo Rural (Timm, 2015). Reading is rare in rural areas. Thus, the information collected in this work points to the need to innovate also in the means of communication for effectively promoting innovation and development in the field. Adapting the digital content to the literacy characteristics of its audiences creates suitable conditions for people to learn

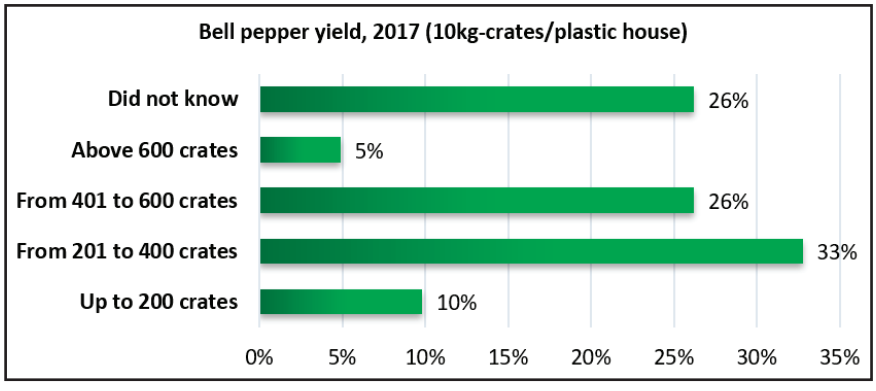

Figure 4. Sweet pepper yield (10kg-crates in 350m^2 standard plastic houses) reached by farmers (%) in protected cultivation, in Planaltina, 2017. Brasília, Embrapa Hortaliças, 2018.

and to appropriate the information, findings, and knowledge which will help to improve and transform their reality (Magalhães *et al*., 2010).

The use of short videos, to be shared via What's App, can be a good strategy for spreading agricultural research and for strengthening farmers' capacity. In our survey, 54% of the farmers did use the messaging app. Some already use What's App to buy agricultural inputs and to sell and send photos of their products, to follow the prices paid at the wholesale market (CEASA), and to exchange information. On the other hand, some have claimed they did not use it due to the lack of internet signal where they live. For this means of communication to grow in relevance, it is necessary to invest in public policies to expand the rural Internet network, which will significantly facilitate the communication with and transference of information to farmers.

Cost of production and productivity

Most farmers (61%) did not control their production costs, while those who control them (39%), did not do it correctly according to the Emater-DF agents who assist them. Farmers did not take into consideration administrative costs, cost of money (interests), depreciation, and the land opportunity cost. One way or another, 82% of the farmers said that production costs have increased in recent years (Figure 5A). The adequate management of production costs would have made it easier to farmers to assess appropriately the opportunity cost of working with other crops and would have assisted them in making decisions regarding the adoption of technologies and in the analysis of the impact of such adoption over their costs and incomes. Presently, farmers ignore which items have weight the most in their production costs, making it difficult to assess the economic viability of their business. Pagliuca *et al*. (2014) reported a similar scenario with tomato producers in the states of São Paulo and Santa Catarina.

The increase in input prices was the primary driver of the increase in production costs for 88% of the farmers. As they could point out more than one reason, 14 and 13% of the farmers also named the increase in the use of pesticides and labor, respectively, as the additional items responsible for increasing production costs. Only 5% of the farmers reported cost reduction. In these cases, costs fell due to the technical assistance received from Emater-DF agents, who helped the farmers to reduce the volume of inputs used and to manage irrigation properly; to the change in technology (farmers who started using mulching); to the absence of greenhouse implementation costs (farmers using greenhouses from the second year); and to the reduction in pest pressure and in input use (pesticides and fertilizers).

When questioned about their perception regarding crop yields, 52% of farmers reported decreases in productivity in the last year (Figure 5), and for 67% of them, the main reason was the increase in the incidence of pests and diseases. Soil exhaustion or imbalance due to the repetition of the same crop in the area was mentioned by 8% of the farmers as one of the reasons for the declining productivity, while 6% attributed it to the suboptimal use of fertilizers and pesticides due to their high prices. Farmers who reported increases in yield (17%) stated the main reasons were improvements in fertilization and irrigation practices (88%), followed by more experience and knowledge of crop management (19%), and detailed crop control, with valuable information for decision making being recorded.

Farmers tend to reduce investment in periods of financial crisis and do not carry out technically recommended practices of crop management due to the low prices paid by the market and to minimize financial losses. Thus, productivity progressively reduces as a consequence of the successive failure to adopt good agricultural practices.

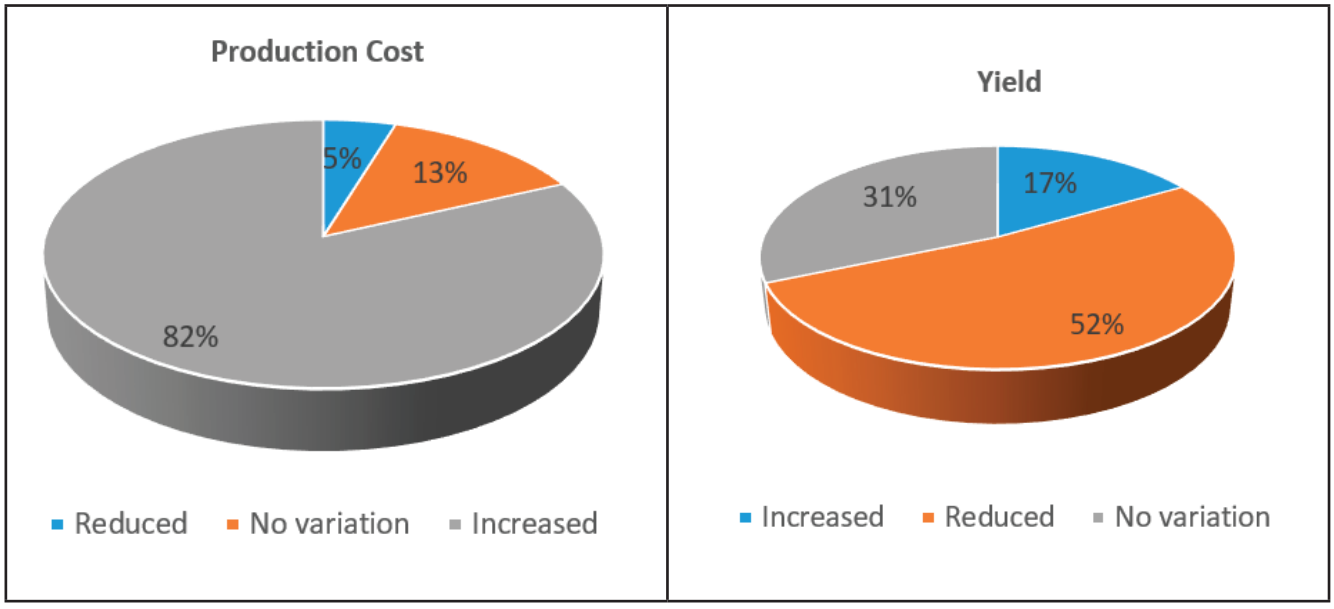

Figure 5. Farmers' perceptions about production costs and variations in crop yield, for protected cultivation in Planaltina. Brasília, Embrapa Hortaliças, 2018.

FINAL REMARKS

The survey was quite useful to draw the profile of the farmers producing vegetables in protected cultivation in the administrative region of Planaltina-DF. Besides, we could identify the technologies that are currently in use or no longer used by them and the possible causes to the yield drops claimed by the majority.

The crisis in the region was due to a combination of several factors, whether from the current conjuncture, such as the decrease in consumption (reduced demand for governmental purchases and from the market) and drops in the prices paid to farmers; and technological, as the decline in yields. Regardless of the cause, the crisis hampers investments in farm improvements. The survey pointed out that the escalation in the incidence of pests and diseases over the years, intensified by the low adoption of good agricultural and management practices, was one of the central causes for the yield drops among other factors.

A set of adjustments and actions on several fronts can revert the adverse scenario: economic, with increases in consumption and prices; technological, with the adoption of technologies, many already available to farmers; technical advisory services, with research and rural extension working closer, and farmer capacity strengthening in integrated pest and disease and in irrigation management, and; farm management, with investments in structures, emphasis on management strategies and farm organization, adoption of good agricultural practices, and use of innovative means of communication. All these factors are essential to regain farmers' economic sustainability. As for the low prices paid to farmers, the use of cooperative marketing strategies and increased access to information about the prices paid by the market can help to increase farmers' bargaining power.

A joint and multidisciplinary work in the region, including the organized producers and the institutions involved in the survey, could foster the recovery of productivity gains and profitability in the production of vegetables in protected cultivation in the region of Planaltina.

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