SILAGE CORN PRODUCTION UNDER DIFFERENT MANAGEMENT STRATEGIES: CONVENTIONAL AND 4.0

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Abstract. Agriculture 4.0 has emerged as a strategic tool to maximize operational efficiency and environmental sustainability in agricultural production. The integration of telemetry, automation, and spatial data analysis facilitates more precise management, reducing input waste and enhancing production predictability relative to traditional methods. In this context, the objective of this study was to evaluate the impact of adopting Agriculture 4.0 technologies on the agronomic performance and productive potential of silage corn, comparing 4.0 and conventional management systems under field conditions. The experiment was conducted at the UNIMAR Experimental Farm in Marília, São Paulo, a region characterized by a humid mesothermal climate (Cwa) and a sandy-textured Ultisol typical of the Midwestern region of São Paulo. A split-block design was employed, featuring two treatments (conventional and 4.0 management) with eight replications per treatment, totaling 16 experimental units. Each unit comprised two rows, two meters long. The commercial hybrid NK501 S1 VIP3 was planted with 0.45 m spacing between rows. The area under 4.0 management (8.5 ha) integrated variable rate soil correction and seeding (VRT), guided by electrical conductivity and fertility maps, and utilizing autopilot and GNSS signal correction. In contrast, the area under conventional management (8.9 ha) received inputs at a fixed rate, without assisted navigation or light bar guidance. Biometric and weed competition evaluations were performed at the V5–V6 stage, including measurements of plant height, stem diameter, leaf area, and shoot fresh and dry biomass. For weed dry mass determination, 0.5 × 0.5 m quadrats were employed. Data were assessed for normality using the Shapiro-Wilk test, followed by analysis of variance (ANOVA) via the F-test ($p \leq 0.05$). No statistically significant differences were observed between the management systems for the evaluated variables. Regarding shoot fresh biomass, while not statistically significant, the 4.0 management system yielded an average of 530.4 g m^{-2}, whereas the conventional system registered 395.2 g m^{-2}. Economically, the 4.0 management system demonstrated savings of R$ 183.80 per hectare compared to the conventional method, highlighting how technology applied to input management can optimize field investment. Weed infestation was similar between systems, with an average dry mass of 12.5 and 11.0 g per sampling quadrat for the 4.0 and conventional managements, respectively. In conclusion, under the conditions of this experiment, the 4.0 and conventional management systems did not statistically differ in terms of the biometric variables and weed competition evaluated during the initial vegetative stage of silage corn. However, they

exhibited differences in economic viability, given that the 4.0 management system more advantageous than the conventional method.

Keywords: Precision agriculture; Variable rate; Agriculture 4.0; IoT; Digital management.

Introduction

Agriculture 4.0 has emerged as a strategic tool to maximize operational efficiency and environmental sustainability in agricultural production (Sanyaolu and Sadowski 2024). The integration of telemetry, automation, and spatial data analysis facilitates more precise management, reducing input waste and enhancing production predictability relative to traditional methods (Sishodia et al. 2020). However, comparative studies on the agronomic and economic impacts of these technologies in silage corn under tropical conditions are still limited (Gyarmati and Mizik 2020). In this context, the objective of this study was to evaluate the impact of adopting Agriculture 4.0 technologies on the agronomic performance, weed competition, and economic viability of silage corn, comparing 4.0 and conventional management systems under field conditions.

Material and Methods

The experiment was conducted under field conditions at the Marcelo Mesquita Serva Experimental Farm, University of Marília (UNIMAR), located in Marília, São Paulo, Brazil (22° 12' 50" S, 49° 56' 45" W, approximately 610 m altitude) (Figure 1). The regional climate is classified as Cwa (Köppen), and the soil is an Ultisol of sandy-loam texture. Two adjacent areas under silage corn production were compared: one under 4.0 management (8.5 ha) and another under conventional management (8.9 ha), using the commercial hybrid NK501 S1 VIP3. The experimental design was a split-block, with two treatments and eight replications (sampling points).

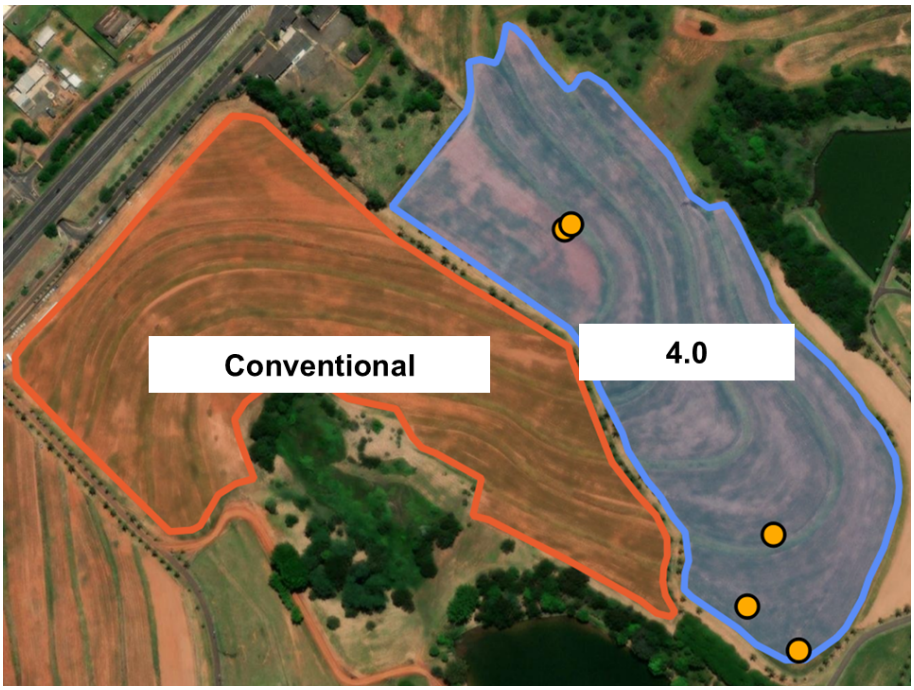

Fig. 1 Detail of the experimental area used for the conventional and 4.0 systems comparison.

In the 4.0 area, precision agriculture technologies were integrated: variable rate soil correction and seeding (VRT), guided by soil fertility and electrical conductivity maps, utilizing light bars, autopilot, and GNSS signal correction. Pest control was based on monitoring via traps and inspections, resulting in four strategic sprays (two via ground boom sprayer and two via

drone). In contrast, the conventional area received inputs at a fixed rate (based on the area average) and followed a scheduled phytosanitary management (two applications via ground sprayer), without light bars, GNSS correction, or autopilot. Topdressing fertilization was identical and homogeneous for both systems. Technological support included spatial management and processing software (QGIS, EKOS, METOS, Dymaxion, and CropMan).

Biometric and weed competition variables were collected at the V5-6 growth stage. In 4-m linear plots, plant height, stem diameter, and leaf area were evaluated, along with total fresh and dry shoot mass to characterize the initial productive potential. Weed flora analysis considered species identification and dry biomass in random 0.5 × 0.5 m quadrats. Data were subjected to assumption tests (Shapiro-Wilk and Levene) followed by analysis of variance (ANOVA) via the F-test ($p < 0.05$).

Results

No statistically significant differences were observed between the management systems for the evaluated biometric and weed competition variables (Table 1). Regarding shoot fresh biomass, while not statistically significant, the 4.0 management system yielded an average of 530.4 g m^{-2}, whereas the conventional system registered 395.2 g m^{-2}. Weed infestation was similar between systems, with an average dry mass of 12.5 and 11.0 g per sampling quadrat for the 4.0 and conventional managements, respectively.

Economically, the 4.0 management system demonstrated savings of R$ 183.80 per hectare compared to the conventional method, highlighting how technology applied to input management can optimize field investment.

Table 1. Silage corn biometric parameters and weed dry biomass under conventional and 4.0 management systems at the V5-6 growth stage.

Treatments	Plant height (m)	Stem diameter (mm)	Leaf area (cm^2)	Shoot fresh biomass (g m^{-2})	Shoot dry biomass (g m^{-2})	Weed dry biomass (g)*
Conventional	0.35	17.03	130.04	395.27	63.05	11.0
4.0 system	0.36	17.63	127.87	530.41	46.25	12.5
F-test	0.55^{ns}	0.12^{ns}	0.02^{ns}	2.95^{ns}	3.87^{ns}	0.04^{ns}

* Dry biomass per 0.25 m². ns Not significant

Economically, the operational cost analysis indicated that the 4.0 system provided a reduction in input expenses, corroborating literature that identifies VRT as an efficient tool for the economic optimization of agricultural inputs.

Conclusion

It is concluded that, under the conditions of this experiment, the 4.0 and conventional management systems did not statistically differ in terms of the biometric variables and weed competition evaluated during the initial vegetative stage of silage corn. However, they exhibited differences in economic viability, given that the 4.0 management system proved more advantageous than the conventional method, demonstrating potential for cost reduction and input optimization.

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