Agronomic and Economic Performance of Early Maize and Weed Management Under Agriculture 4.0 versus Conventional Systems

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Abstract.

Agriculture 4.0 represents an essential strategy to optimize operational efficiency and environmental sustainability in maize cultivation, enabling rational use of inputs through automation and data management. However, there is limited comparative information on its agronomic effectiveness compared to conventional practices under tropical conditions. Therefore, the objective of this study was to compare vegetative development and weed infestation in conventional cultivation systems or Agriculture 4.0. The experiment was conducted at the UNIMAR Experimental Farm, Marília/SP, Brazil, in a sandy-loam textured Ultisol, Cwa climate, at 610 m altitude. The experimental design was a strip plot, with two treatments (4.0 management with 19.3 ha and conventional with 16.6 ha) and eight replications, using the DKB358 PRO4 hybrid, sown at 0.45 m row spacing. In the 4.0 system, precision technologies were adopted: soil correction and variable rate seeding (VRT), electrical conductivity sensors, light bars, automatic pilot, and GPS correction. Phytosanitary management was based on weekly monitoring and traps, performing sprays only when reaching the control level (five applications via drone/ground boom sprayer). In the conventional system, operations occurred at a fixed rate, without precision agriculture tools, following a pre-established calendar (two sprays). Evaluations were conducted at the V5-6 growth stage, measuring stem diameter, number of leaves, and shoot phytomass (fresh mass). Simultaneously, weed dry mass was determined using 0.5 × 0.5 m quadrats. Data were tested for normality and homogeneity of variances, subjected to analysis of variance (ANOVA) by the F-test, at 5% probability. Fresh shoot mass, stem diameter, and number of leaves did not differ between the two management systems. Similarly, weed dry mass did not differ between cultivation systems. On the other hand, due to the use of variable rate for the distribution of lime, gypsum, and seeds, the cost of these operations was lower in the 4.0 system (R$ 1,515.28) compared to the conventional system (R$ 1,718.34). That is, the 4.0 system provided a 12% reduction in the cost of these operations. It is concluded that, although the cultivation system did not influence growth parameters, the 4.0 system contributed to cost reduction and optimization of input use.

Keywords. Precision Agriculture; Vegetative Development; *Zea mays*; Agricultural Mechanization.

Introduction

Agriculture 4.0 represents an essential strategy to optimize operational efficiency and environmental sustainability in maize (*Zea mays* L.) cultivation, enabling rational use of inputs through automation and data management (Sanyaolu & Sadowski 2024). The application of technologies such as remote sensing, variable rate technology (VRT), and real-time phytosanitary monitoring aims to maximize productivity while reducing operational costs and environmental impacts (Sishodia et al. 2020). However, there is limited comparative information on the agronomic effectiveness of these practices versus conventional systems under tropical conditions, particularly regarding initial vegetative development and weed dynamics (Gyarmati & Mizik 2020). Therefore, the objective of this study was to compare vegetative development, weed infestation, and economic efficiency between conventional cultivation systems and Agriculture 4.0 in maize production.

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 State, Brazil (22° 12' 50" S, 49° 56' 45" W, approximately 610 m altitude) (Figure 1). The regional climate is classified as Cwa according to the Köppen classification (tropical humid mesothermal), and the soil is classified as a sandy-loam textured Ultisol. Two adjacent areas were compared: one under Agriculture 4.0 Management (19.3 ha) and another under Conventional Management (16.6 ha), using the same maize hybrid (DKB358 PRO4). The experimental design was in strips with two treatments and eight replications.

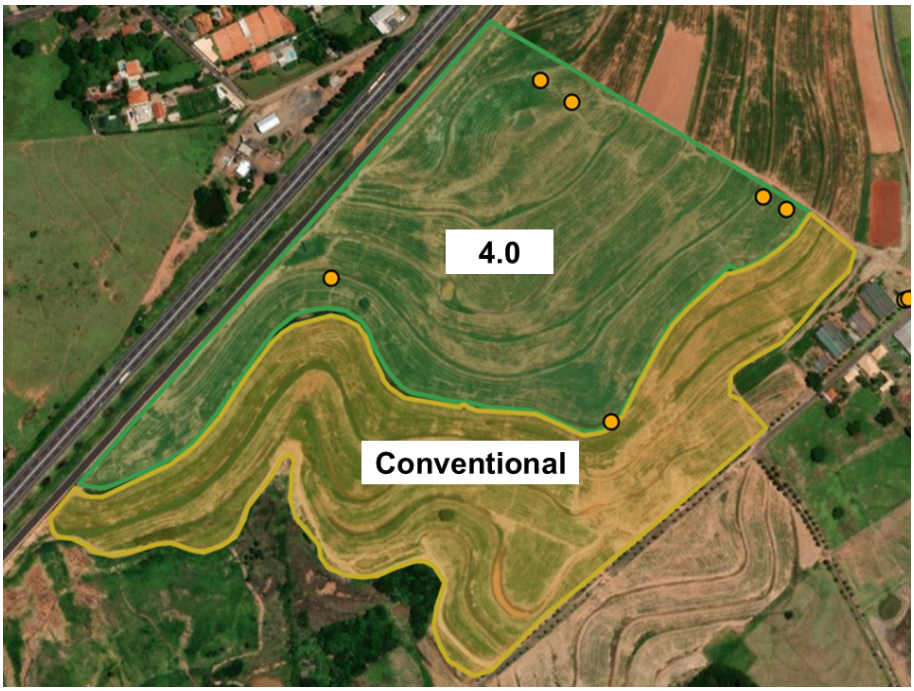

Fig. 1 Detail of the experimental area used for the conventional and 4.0 systems comparison.

In the Agriculture 4.0 system, interventions were based on Precision Agriculture: soil correction (liming and gypsum application) and variable rate seeding (VRT), along with the use of electrical conductivity sensors for soil scanning. Machinery operated with light bars, line projection, automatic pilot, and GPS signal correction. Phytosanitary monitoring was conducted via electronic traps and weekly inspections, with sprays (via ground equipment and drone) applied only when control levels were reached, totaling five applications. In the Conventional

Management system, operations (soil correction and planting) were performed at fixed rates without the use of light bars, precision GNSS, or automatic pilot, and sprays followed a fixed calendar, with only two applications throughout the crop cycle, according to routine farm practices.

Evaluations were conducted at the V5-6 growth stage. In each experimental unit (two rows of 2 m), the following were measured: stem diameter, number of leaves, and shoot fresh mass. Simultaneously, the weed community was assessed in 0.5 × 0.5 m quadrats, determining dry mass. Data were previously subjected to normality (Shapiro-Wilk) and homogeneity of variance (Bartlett or Levene) tests. Subsequently, analysis of variance (ANOVA) was performed using the F-test at 5% probability.

Results

Fresh shoot mass, stem diameter, and number of leaves did not differ statistically between the two management systems ($p > 0.05$) (Table 1). Similarly, weed dry mass showed no significant difference between cultivation systems, indicating that monitoring and targeted applications in the 4.0 system were as effective in controlling the weed community as the fixed calendar of the conventional system (Table 1).

Table 1. Maize growth parameters and weed infestation in conventional and 4.0 areas.

Treatments	Stem diameter (mm)	Leaves number	Shoot fresh biomass (g)	Weed dry mass (g)
Conventional	18.84	6.34	990.50	11.96
4.0 system	16.37	6.15	646.25	6.76
F test	1.43^{ns}	0.11^{ns}	4.36^{ns}	5.33^{ns}

ns: Not significant

On the other hand, due to the use of variable rate for the distribution of lime, gypsum, and seeds, the operational cost for these activities was lower in the 4.0 system (R$ 1,515.28) compared to the conventional system (R$ 1,718.34). This represents an approximately 12% reduction in the costs of these specific operations, corroborating the literature that points to VRT as an efficient tool for the economic optimization of agricultural inputs.

Conclusion

It is concluded that, although the cultivation system did not influence initial vegetative growth parameters and weed biomass, the Agriculture 4.0 system contributed significantly to reducing operational costs and optimizing input use, demonstrating its technical and economic viability for maize cultivation under tropical conditions.

References

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