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Evaluation of agronomic performance of local and improved maize (*Zea mays* L.) varieties under weeds pressure

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Abstract

Maize (*Zea mays* L.) is the second most cultivated cereal after rice in Côte d'Ivoire. It is widely used in both human and animal diets across many communities. However, its production remains faced with recurrent yield declines, mainly related to weeding. Identifying maize variety with the highest performance against weeds could constitute the most appropriate solution in the agro-economic context of most farmers. Two weeding techniques, namely manual and chemical, and a control modality without weeding were applied to three maize varieties: yellow, purple and EV8728 SR. Their phenological, growth and agronomic parameters were evaluated. The results showed that manual weeding was more effective for weed control in maize. In addition, the comparison of all three varieties faced with severe weed pressure on non-weedy plots showed that purple variety recorded the lowest values, yellow variety showed intermediate values, while EV variety clearly stood out for its strong ability to grow and maintain high agronomic performance. Further studies may allow us to search for genes responsible for the tolerance of the EV variety involved in weed tolerance

Keywords: *Zea mays*; Weed; Maize Varieties; Manual Weeding; Chemical Weeding

1. Introduction

Maize (*Zea mays* L.) is one of the main cultivated species in the world. It plays an important role in both human and animal nutrition (poultry, pigs, cattle) in Sub-Saharan Africa. It is also widely used in the agri-food industry for oils, starches, and alcohols productions, making it a strategic crop from both nutritional and economic standpoint [1].

However, despite its socio-economic importance, maize cultivation faces many challenges that hinder its production. Mean yields of traditional varieties in farming communities are approximately 0.8 tons per hectare, compared to 6 to 8 tons per hectare in research stations [2]. The main causes of yield decline are believed to be linked to soil infertility, the emergence of diseases and pests, and especially the presence of weeds [3]. In fact, weeds remain the major constraint to maize production. Indeed, competition with weeds in tropical regions can result in yield losses of over 50 % [4]. Furthermore, weeds have detrimental effects on all phenological phases of the plants. They cause a slowdown or even complete cessation of growth and development in maize plants [5].

Considering weeds significant effect on crops, many studies have been undertaken, focusing mainly on chemical control strategies [6, 7]. Farmers due to its ease of application, reduced labor requirements, and time efficiency, making it a comparatively cost-effective option, generally favor this approach. Nevertheless, emergence of herbicide-resistant weed

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species remains a persistent challenge. Consequently, there is an urgent need to develop alternative solutions that are accessible to smallholder farmers.

For most farmers, identifying maize genotypes tolerant to weed competition is one of the most appropriate solutions in their agro-economic context. Tolerant varieties have the advantage of increasing yields despite weeds presence [8]. Within this framework, the present study was undertaken to enhance maize productivity by identifying the variety demonstrating the greatest performance under weed-infested conditions.

2. Materials and methods

2.1. Study site

The experiment was conducted in march 2025 on the experimental plot of Nangui Abrogoua University (5°23′19″ N latitude and 4°0′54″ W longitude) in the southern of Cote d'Ivoire (Figure 1).

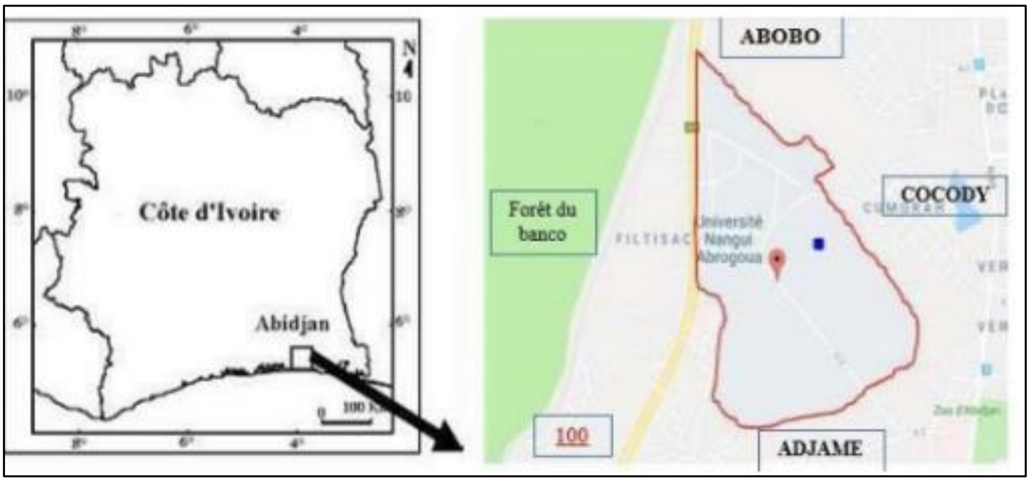

Figure 1 Location of the study site [9].

2.2. Plant material

Seeds of three maize varieties: purple maize (Figure 10 A) and yellow maize (Figure 10 B) both from seed bank of the Plant Physiology Laboratory, and the improved EV 8728 SR (Figure 10 C) were used in this study. The last variety, is a seed line developed by the National Center for Agronomic Research (CNRA) for enhanced growth, disease resistance, and high yield potential.

A B C

Figure 2 Maize of the purple (A), yellow (B), and EV 8728 SR (C) varieties

2.3. Experimental setup

The experimental design followed a randomized complete block layout, covering a total area of 117 m² (13 m × 9 m). It consisted of three blocks, each subdivided into nine elementary plots separated by 0.5 m wide alleys, with a 1 m spacing between blocks to facilitate movement and field operations. Each block was arranged in ridges measuring 2 m in length, 1 m in width, and 0.30 m in height, giving an area of two m² per elementary plot. Within each elementary plot, the maize plants were arranged in two rows of five points spaced 0.3 m apart, and 0.5 m between rows. The experiment was based on three distinct treatments: two weeding methods (manual and chemical) and a control. Each treatment was three times replicated. A week after seedlings transplanting, a thinning operation was carried out to leave only one vigorous plant per hole. Weeds were removed using a hoe for manual weeding. Chemical weeding was carried out by targeted application of a selective herbicide based on nicosulfuron, at a dose of between 75 and 120 ml per 15 L of water, applied evenly to effectively eliminate weeds without affecting the crop.

2.4. Measured variables

During this study, growth, phenology, and yield parameters were rigorously monitored throughout the maize development cycle from the early stages of vegetative growth to harvest.

Three phenological parameters (the timing of male and female flowering and the duration of ear maturation), seven growth parameters (width, length and number of leaves, plant height, branch number, root length and number, and collar diameter), and four yield parameters (weight of grains, number of grains, weight of plants and ears) were evaluated according to [10].

2.5. Statistical analysis of experimental data

All data collected during this study were subjected to statistical analysis to assess the influence of both experimental factors (maize varieties and weeding methods) using STATISTICA software version 7.1 [10]. To this end, the Analysis of Variance (ANOVA) was performed to compare the means of different phenological, growth, and agronomic parameters across the three treatments (manual weeding, chemical weeding, and control) in order to determine the most suitable treatment.

A separate ANOVA was also conducted to compare the means of all measured parameters among the three maize varieties. When a significant difference was detected between varieties for a given parameter, the ANOVA was followed by the least significant difference (LSD) test. This test enabled the identification of the variety exhibiting the best agronomic performance under weed-infested conditions.

3. Results

3.1. Effect of weeding methods on phenological and growth parameters

Table 1 Effect of weeding method on maize phenological and growth parameters

Parameters[1]		**Weed control method**			***Satistics***[2]	
		Chemically	Manually	Control	*F*	*P*
Phenoloical	AnTi (DAT)	47.57 ± 3.284^{a}	47.51 ± 4.206^{a}	51.31 ± 5.310^{b}	22.601	< 0.001
	CoET (DAT)	55.64 ± 4.607^{a}	56.10 ± 6.246^{a}	62.22 ± 5.958^{b}	38.054	< 0.001
	CoMT(DAT)	77.99 ± 4.840^{a}	77.68 ± 4.637^{a}	90.52 ± 4.468^{b}	223.417	< 0.001
Growth	RoNb	28.37 ± 4.507^{b}	25.63 ± 2.553^{a}	29.20 ± 4.895^{b}	6.169	0.003
	RoLe (cm)	20.60 ± 2.660^{b}	22.37 ± 3.479^{c}	18.50 ± 2.801^{a}	12.479	< 0.001
	LeLe (cm)	4.9763 ± 1.981^{a}	4.9373 ± 1.931^{a}	5.0095 ± 2.013^{a}	0.050	0.951
	LeWi (mm)	51.046 ± 25.307^{a}	51.426 ± 25.427^{a}	47.2721 ± 22.975^{a}	1.308	0.271
	PlHg (cm)	105.795±587.320^{a}	59.1917±37.471^{a}	54.4101 ± 30.696^{a}	1.044	0.353
	NuLf	7.016 ± 2.098^{a}	7.413 ± 2.314^{a}	6.840 ± 2.183^{a}	2.672	0.070
	StCD (mm)	13.096 ± 6.115^{b}	13.642 ± 6.285^{b}	11.488 ± 55.133^{a}	5.452	0.005

[1]AnTi : anthesis time, CoET : cob emergence time, CoMT : cob maturation time, RoNb: root number/ plant, RoLe: root lengh, PlHg: Plant heigh, NuLf: number of leaves, StCD: stem collar diameter, DAT: days after transplantation; [2] F-statistics and P: probability associated with the test. For each parameter, values with the same superscript letters are statistically equal (P ≥ 0.05)

The weeding method had a significant effect on the three phenological parameters ($P < 0.05$). Specifically, the timing of male and female flowering and the duration of ear maturation were higher on unweeded plots than in manually and chemically weeded plots (Table 1). Thus, weed infestation delayed the phenological parameters.

In contrast, the weeding method did not affect growth parameters, except for root length and number. Compared to manual weeding, chemical weeding increased the number of roots while reducing their length.

3.2. Effect of weeding technique on agronomic parameters

Table 2 presents values of agronomic parameters related to maize cobs and grains measurements following weed control method. Statistical analysis results revealed significant difference between all agronomic parameters following three treatments. Thus, plant, cobs, number and grain weights, were highest in manually weeded plots, followed by chemically weeded plots and then untreated plots.

Table 2 Effect of weeding method on agronomic parameters

Parameters	Weed control method			Statistics	
	Chemically	Manually	Control	*F*	*P*
Plant weight (g)	346.67 ± 103.130^{b}	298.08 ± 118.67^{b}	171.83 ± 54.005^{a}	10.610	< 0.001
cob weight	132.92 ± 52.254^{b}	152.92 ± 35.364^{c}	67.67 ± 17.619^{a}	16.673	< 0.001
Grains/ plant	253.33 ± 97.811^{b}	366.08 ± 75.138^{c}	132.92 ± 69.255^{a}	24.463	< 0.001
Grain weight (g)	261.900 ± 50.578^{b}	359.967 ± 71.384^{c}	105.067±30.983^{a}	17.272	0.003

3.3. Estimation of phenological parameters for the three varieties

Values of the phenological parameters recorded during the development of maize three varieties studied (yellow, purple, and EV) are presented in Table 3. Statistical analysis of data from weeded plots revealed no significant variation in stamens appearance time of female flowering or cob maturation. In contrast, the date of male flowering was significantly influenced by the varieties ($P < 0.001$). Stamens earlier appeared in the EV variety than in the other two varieties. The male flowers of the EV variety appeared earlier than those of the other two varieties. On the unweeded control plots, a significant difference was observed for all parameters. The male and female flowers appeared earlier for the yellow variety. However, the EV variety matured earlier than the other varieties. The Yellow and Purple varieties had a later reproduction time, although the female flowers appeared earlier than the EV variety. The difference in ear maturity time between the two treatments for the three varieties was lower for the EV variety (-9.03%) than for the Yellow (-15.57%) and Purple (-18.09%) varieties.

3.4. Variation in growth parameters according to weeding in three maize varieties

Statistical analysis of growth parameters revealed that plant height and leaf dimensions (length and width) varied significantly depending on whether the plants were weeded or not (Tables 4 and 5). The EV variety had broader leaves than both varieties. For leaf length and plant height, both the EV and yellow varieties exhibited the highest values in weeded and unweeded plots. Quantification of the relative reductions in these discriminating parameters showed that the EV variety expressed the lowest losses, with only a 3.04% reduction in leaf width, 6.47% in leaf length, and 2.1% in plant height. This was followed by the purple variety, with losses of 1.71%, 7.73%, and 3.66%, respectively, and finally the yellow variety, which was the most sensitive, exhibiting losses of 35.55%, 14.56%, and 8.68% respectively.

3.5. Impact of weed control on agronomic parameters of three maize varieties

Statistical analysis of agronomic parameters showed a significant difference for all measured parameters across all treatments, except for the number of grains in the weeded plot (Table 4). In the unweeded control plots, the effects of competition from weeds resulted in a marked decrease in the mean values of the various parameters. The EV variety stood out with superior performance, exhibiting a seed weight loss of only 15%, compared to 27% for both the yellow and purple varieties.

Table 3 Estimation of phenological parameters for the three varieties

Maize varieties	Date of stamen appearance			Date of cob appearance			Date of cob maturation		
	Weeded	Control (unweeded)	Loss (%)	Weeded	Control (unweeded)	Loss (%)	Weeded	Control (unweeded)	Loss (%)
EV	47.60 ± 2.49[b]	50.27 ± 4.18[a]	-5.60	56.10 ± 5.19[a]	63.80 ± 5.37[b]	-13.72	75.45 ± 6.51[a]	82.27 ± 6.49[a]	-9.03
Yellow	46.22 ± 3.46[a]	49.93 ±4.25[a]	-8.02	54.98 ± 5.12[a]	59.60 ± 6.00[a]	-8.40	77.93 ± 4.30[a]	90.07 ± 5.03[b]	-15.57
Purple	48.80 ± 4.62[b]	53.73 ± 6.45[b]	-10.10	56.53 ± 6.04[a]	63.27 ± 5.75[b]	-11.92	76.55 ± 5.64[a]	90.40 ± 3.85[b]	-18.09
F	7.60	5.15		1.28	4.79		3.005	23.16	
P	< 0.001	0.008		0.280	0.011		0.052	< 0.001	

Table 4 Impact of weed control on growth parameters in three maize varieties

Maize varities	Leaf length (cm)			Plant height (cm)			Number of leaves			Leaf width (cm)		
	Weeded	**Control (unweeded)**	**Loss (%)**	**Weeded**	**Control (unweeded)**	**Loss (%)**	**Weeded**	**Control (unweeded)**	**Loss (%)**	**Weeded**	**Control (unweeded)**	**Loss (%)**
EV	60.93±21.56[b]	56.98±21.32[b]	6.47	67.25±32.159[b]	65.83±25.20[b]	2.10	7.83±5.58[a]	7.61±1.93[a]	2.896	5.59±2.11[a]	5.421±1.97[c]	3.04
Yellow	61.23±22.29[b]	52.30±21.398[b]	14.56	71.07±34.74[b]	64.90±30.72[b]	8.68	7.640±4.50[a]	6.89±4.40[a]	9.816	6.99±8.90[b]	4.507±1.52[b]	35.55
Purple	51.23±25.32[a]	47.27±22.97[a]	7.736	52.48±30.99[a]	54.41±30.69[a]	3.667	7.21±2.21[a]	6.84±2.18[a]	5.197	4.95±1.95[a]	3.889±1.463[a]	21.71
F	18.154	7.374		27.090	7.186		1.612	3.011		11.178	31.85	
P	< 0.001	< 0.001		< 0.001	< 0.001		0.200	0.050		< 0.001	< 0.001	

In the same column, figures followed by the same letter are statistically identical at the 5% threshold., ; D: Not weeded

Table 5 Impact of weed control on agronomic parameters of the three maize varieties

Maize varieties	Plant weight (g)			Cob weight of the ear with Spath (g)			weight of grains (g)			Number of grains		
	Weeded	**Control (unweeded)**	**Loss (%)**	**Weeded**	**Control (unweeded)**	**Loss (%)**	**Weeded**	**Control (unweeded)**	**Loss (%)**	**Weeded**	**Control (unweeded)**	**Loss (%)**
EV	387.17±56.36[b]	306.58±101.07[b]	20.81	133.08±35.03[c]	96.17±27.19[b]	27.735	40.20±10.07[c]	29.314±5.14[b]	27.089	230.00±82.57[a]	196.33±37.70[b]	14.63
Yellow	348.13±108.13[b]	217.58±73.56[a]	37.50	108.46±30.38[b]	73.25±21.29[a]	32.463	32.73±11.02[b]	23.673±4.24[b]	27.68	210.33±72.90[a]	138.33±41.88[a]	34.23
Purple	272.79±74.30[a]	171.83±171.83[a]	36.985	81.33±23.60[a]	67.67±17.61[a]	16.795	25.03±5.56[a]	21.116±3.20[a]	15.68	188.87±45.92[a]	107.92±46.13[a]	42.68

In the same column, figures followed by the same letter are statistically identical at the 5% threshold., ; D: Not weeded

4. Discussion

Weeding is one of the main factors limiting the production of cultivated plants. Its management increasingly represents a major challenge for achieving good crop yields. This study aimed at improving maize production with higher-performing varieties in the presence of weeds.

Phonologically, based on different weeding methods, stamens and cob appearance, and maturity were identical on plots weeded manually and chemically. These parameters, however, were longer in unweeded plots. Weeds therefore had a negative impact on the stages of maize development. This finding was verified by [5] and [11], who showed that weed growth slows down the various phenological phases of maize. Regardless of the type of treatment, plant height, leaf width, leaf length, and the number of leaves did not vary between plots. However, the number of roots was higher in chemically weeded and unweeded plots. Indeed, during manual weeding, some maize roots were damaged, thereby reducing their number. The best agronomic performances were recorded in manually weeded plots, followed by chemically treated plots and control plots. Our results were consistent with those of [12], who showed that manual weeding was more effective for controlling weeds in maize. This technique allows for soil leveling, improves porosity, and reduces water loss and runoff. However, according to [13], the best way to manage weed infestation is to combine mechanical weeding with herbicides. Nevertheless, the issue of herbicide resistance in certain weeds, along with the long time required for manual weeding, has shown that identifying weed-tolerant varieties remains the most appropriate solution [14].

Screening of varieties against competition from weeds showed that weeds significantly delay flowering and ear maturation in all three varieties. These results confirm the observations of [15] on the phenological sensitivity of maize varieties under conditions of total weed cover. The shortest delay in ear maturity (9%) was obtained with the EV variety between weeded and unweeded plots. This reveals its high resilience in competition with weeds compared to the other two varieties, which showed delays of 15% and 18% respectively.

The evaluation of agronomic parameters revealed that the EV variety once again stood out for its ability to maintain high agronomic performance, even under weedy conditions, reflecting better weed tolerance. These results could be explained by the fact that EV is an improved variety developed by the National Centre for Agricultural Research (NCAR) for optimal growth and disease resistance. Its ability to limit performance losses under stress conditions indicates high competitiveness with weeds. These findings are consistent with those of [16], who demonstrated that certain maize varieties exhibited greater resilience to competition from weeds. Thus, a judicious varietal selection can significantly reduce yield losses due to weed infestation by identifying those with the highest competitive ability ([17]. However, the purple variety is the most sensitive to weeds, exhibiting reduced growth and overall lower yield in unweeded plots. The yellow variety occupies an intermediate position.

5. Conclusion

The present study aimed to identify the maize variety with the highest agronomic performance for improving maize productivity in Côte d'Ivoire. The results revealed that weed infestation delays the different phenological stages of maize, while weeding significantly enhanced both vegetative and reproductive development. The best agronomic performances were observed in manually weeded plots, followed by chemically treated plots, and finally the control plots. The EV variety clearly distinguished itself by maintaining high agronomic performance even under non-weeded conditions, indicating greater tolerance to weed competition.

Compliance with ethical standards

Disclosure of conflict of interest

The authors have not declared any conflict of interests.

Author Contributions

Anzara and Tano implemented the field trial.

Yao and Anzara performed the statistical analysis and drafted the manuscript.

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