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Research Article

EFFECTS OF SOWING PRACTICE AND WEED CONTROL METHOD ON GROWTH AND YIELD OF TWO MAIZE VARIETIES (*ZEA MAYS* L.) CULTIVATED IN CÔTE D'IVOIRE

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ABSTRACT
In view of improving maize (*Zea mays* L.) yield, still declining due to the actual climatic changes and the new cultural practices, the effects of sowing practice and weeding method were studied in two different varieties (endemic purple and introduced yellow) grown in Katiola (Central-northen, Côte d'Ivoire). For this purpose, grains of both varieties were sown following two practices (on flat and slope) at the experimental field of Nangui Abrogoua University. From sowing to harvest, maize plants were weeded following two methods (manual and chemical) and an unweeded treatment constituted the control. The growth (number of leaves/ plant, leaf size), phenological (stamens appearance date, cob appearance and maturation dates) and yield (cob weight, grains size and yield) parameters were accessed through the analysis of variance (ANOVA 3) test. As results, change in sowing practice (from flat to slope) significantly ($P < 0.05$) favored plant growth by increasing the leaves number and size of yellow and purple varieties. As compared to the control (unweeded plants), weed control methods (manual and chemical) improved maize plants growth, phenology and yield in both varieties. The positive interaction (sowing practice × weeding method) revealed that the best performances (heaviest cobs carrying biggest grains leading to highest yield) were obtained with slope sowing and manual weeding followed by chemical one in both varieties. Despite the relatively lower yield of purple variety (2050.00 Kg/ ha) compared to yellow one (2266.67 Kg/ha), its cultivation should be encouraged due to its endemic character.

Keywords *Zea mays* L., *Endemic Varieties, Sowing Practice, Weeding Methods, Yield*

INTRODUCTION
Maize (*Zea mays* L.) is an annual plant grown mainly for its starch-rich grains and long stalks and leaves for fodder. The high and growing global need for maize is due to its multiple uses, including human and animal consumption (Khoner *et al*, 2018). Maize is also exploited in industry for edible and cosmetic oils and in breweries for alcohol production (Boone *et al*., 2008, Shah *et al*., 2015; Shapna *et al*., 2020).
In Côte d'Ivoire, long believed to be a simple subsistence product, maize is now being intensively cultivated. It constitutes the second most cultivated cereal of the country after rice (*Oryza spp*.) because of the increasing economic importance of its production (Deffan *et al*., 2015). Unfortunately, maize cultivation is subject to many constraints leading to yield decline. Small-scale farmers of whom the majority produce only 1 to 2 tons maize grains per agricultural season (Boone et al., 2008) provide first, maize most national production. Practically all this national production comes from ordinary varieties among which some are traditional and play very important socio-cultural roles. That is the case of purple variety, mainly grown in Katiola and its surrounding areas (Kouakou *et al*., 2010). Besides its good organoleptic quality, this purple variety, exhibits therapeutic virtues. Studies also reported this purple variety to be a natural source of anthocyanins, natural antioxidants, that can prevent cardiovascular diseases, combat cellular aging, reduce cholesterol (LDL) and normalize blood pressure (Mattiolli *et al*., 2020). However, this variety is steadily declining in recent years (Lago *et al*., 2014).
Globally, maize yield decline is combined with poor soils, seasonal fluctuations, parasitic pressures, and weed competition. Many studies largely reported the very high sensitivity of maize to weed competition during the first weeks after emergence and early stages of growth (Gantioli *et al*., 2013). This is the case of Katiola purple variety. Indeed, this sensitivity is reflected in field yield reductions experienced because of early weed competition with the plants. *Striga*, a parasitic weed infestation can lead to the abandonment and disappearance of certain maize varieties (Akanvou *et al*, 2010). In addition, because of Katiola purple maize variety great sensitivity to drought related to the actual climatic changes and the weeds infestation requiring a sowing on

ridge, young farmers of this region prefer growing the new improved yellow varieties appearing to better tolerate these constraints. In addition, according to Mukhtar and Eneminyene (2018), facing weed threats in maize, several control techniques have been adopted manual, mechanical and chemical weeding, and weed tolerant varieties. While effective, manual weeding remains laborious and requires increasing labor as the cultivated area increases (Sims *et al.,* 2018).
Therefore, herbicide use emerged as a method of crop control and protection against weed infestation (Bouhhache *et al.*, 2014). Despite the efficiency and speed action of chemical weed killers, they present many disadvantages. Indeed, when improperly used, chemical pesticides, especially herbicides, impoverish soil, contaminate groundwater and accumulate in the trophic chain (Gala *et al.*, 2007). In addition, several studies showed that the grassing level of a crop depends on sowing method (flat or slope). Lamichhane and Soltani (2020) showed that sowing on a ridge or seedbeds reduces weediness in maize and increases its production. However, ridge sowing is a very laborious and time-consuming operation. In Africa, the crying lack of agricultural machinery requires a large workforce that is nowadays becoming scarce due to the rural migration (Mercandalli *et al*., 2019). Development of practical management solutions may help farmers to reduce their production costs and thus increase yield (Lamichhane and Soltani, 2020). This is probably why maize current farmers of Katiola prefer direct sowing on flat that is relatively easier and faster.
In view of these trends in the change of cultivation techniques and weeding methods, they must be studied and compared in order to propose the best technical itinerary for optimal maize production. This study aims at improving maize production by analyzing the effect of maize sowing practice combined to the weed control methods through the evaluation of the agronomic parameters.

MATERIALS AND METHODS

Plant material

It composed of grains of *yellow* and *purple* varieties (**Figure 1**) collected from a local farmer of Katiola (Côte d'Ivoire)**.**

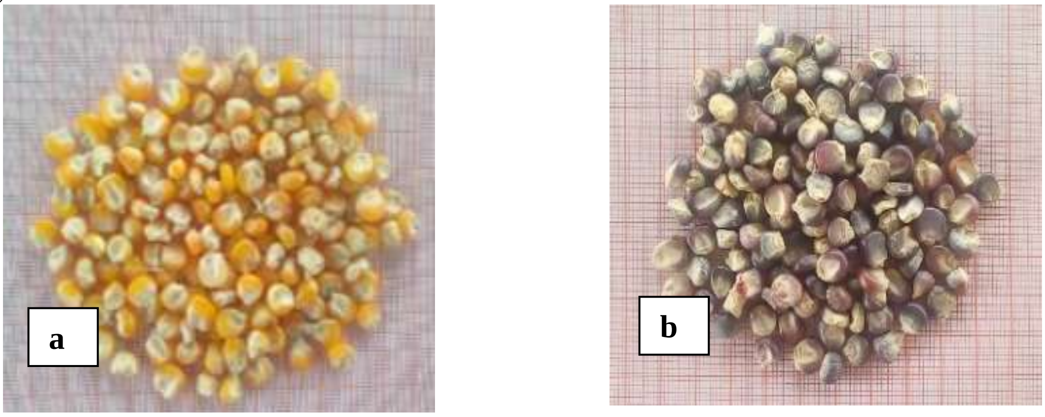

Figure 1. Yellow (a) and purpule (b) grains of mayze

Methods

Plot layout, grain sowing and plant caring.

The experimental sowing device was a rectangular plot of 24 m × 12 m, i.e. an area of 264 m^2, with three blocks or replications. The set-up began with weeding by hoe and the debris was collected and burned. Each block consisted of twelve sub-plots. Elementary subplots were surface of 2 m × 1 m with two rows of five sowing holes spaced 0.40 m together and the rows 0.60 m from each other. In both blocks, six ploughed subplots with 30 cm high beds or slopes were confectioned for ridge sowing and the other six unploughed subplots were used for flat sowing. Before sowing, 500 g of well-decomposed pig manure were added and mixed into each hole. In addition, maize grains of both varieties (*yellow* and *purple*) intended for sowing were pre-germinated (Figure 2) after soaking in tap water for 24 h followed by air-drying for 48 h including a rinse with tap water every 24 h. Some farmers in Katiola (an endemic area for violet cultivar) inspired this technique for the maize establishment. It allowed distinguishing and separating viable grains from the non-viable ones in order to favor a homogeneous germination. The seedlings of both varieties were sown at a ratio of three pre-germinated grains per hole at 3 cm depth either flat (Figure 3 a) or on a ridge (Figure 3 b). Two weeks after emergence, weeding was carried out to keep only one vigorous plant in each hole. Weed control was the main plot maintenance through weeding. For this purpose, two methods were applied manual weeding and chemical weeding. Manual weeding was performed with a hoe to maintain the sub-plots previously designated for this treatment. Chemical weeding was carried out

with selective grass herbicide (Herbigro 720 EC) at a dosage of 40 ml per 15 l of water (i.e. one backpack watering can). In addition, subplots never weeded so permanently grassed constituted the control (Figure 12). In order to prevent insect defoliation, all subplots were treated with an insecticide (Viper 46 EC) from sowing to harvest.
In sum, each block consisted of twelve treatments (two varieties, two sowing techniques and two types of weed control including a control).

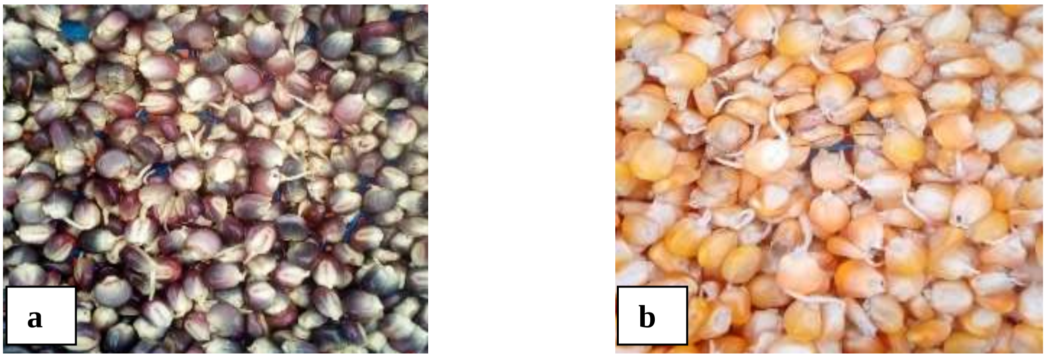

Figure 2: Pre-germinated grains of the maize purple (a) and yellow (b) varieties

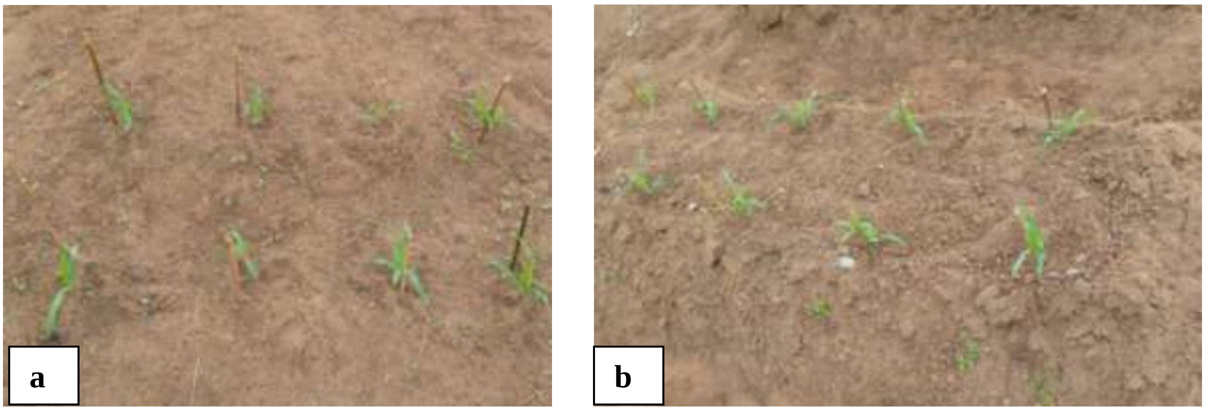

Figure 3: Maize plants from flat (a) and slope (b) sowings

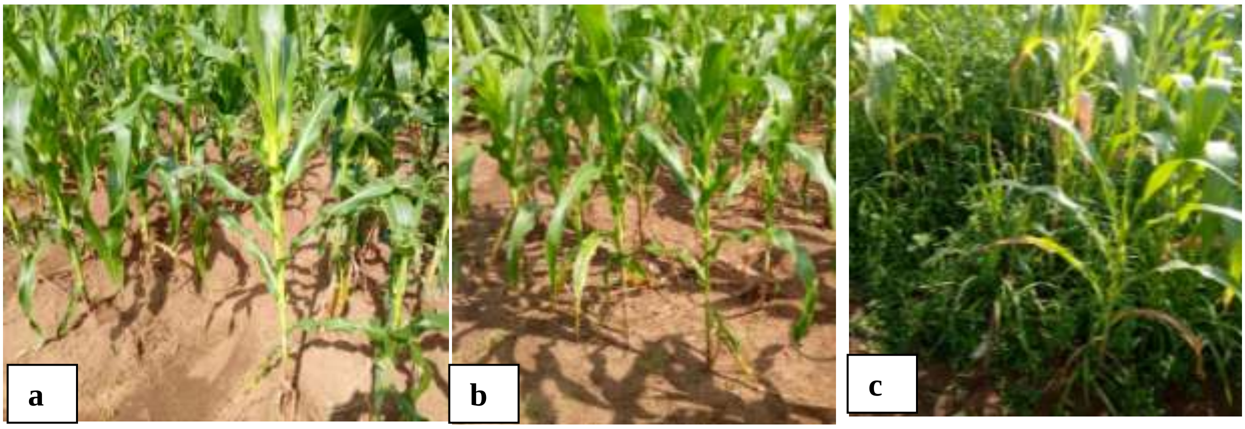

Figure 4: Aspect of manually (a) and chemically (b) weeded maize plants compared to unweeded control (c) on sub-plots

Harvest and post-harvest processing
When the cobs were mature, characterized by the spathes turning from green to brown, they were manually harvested by separating them from the stems bearing them. The spathes were removed from the harvested cobs for measurement (Figure 5).

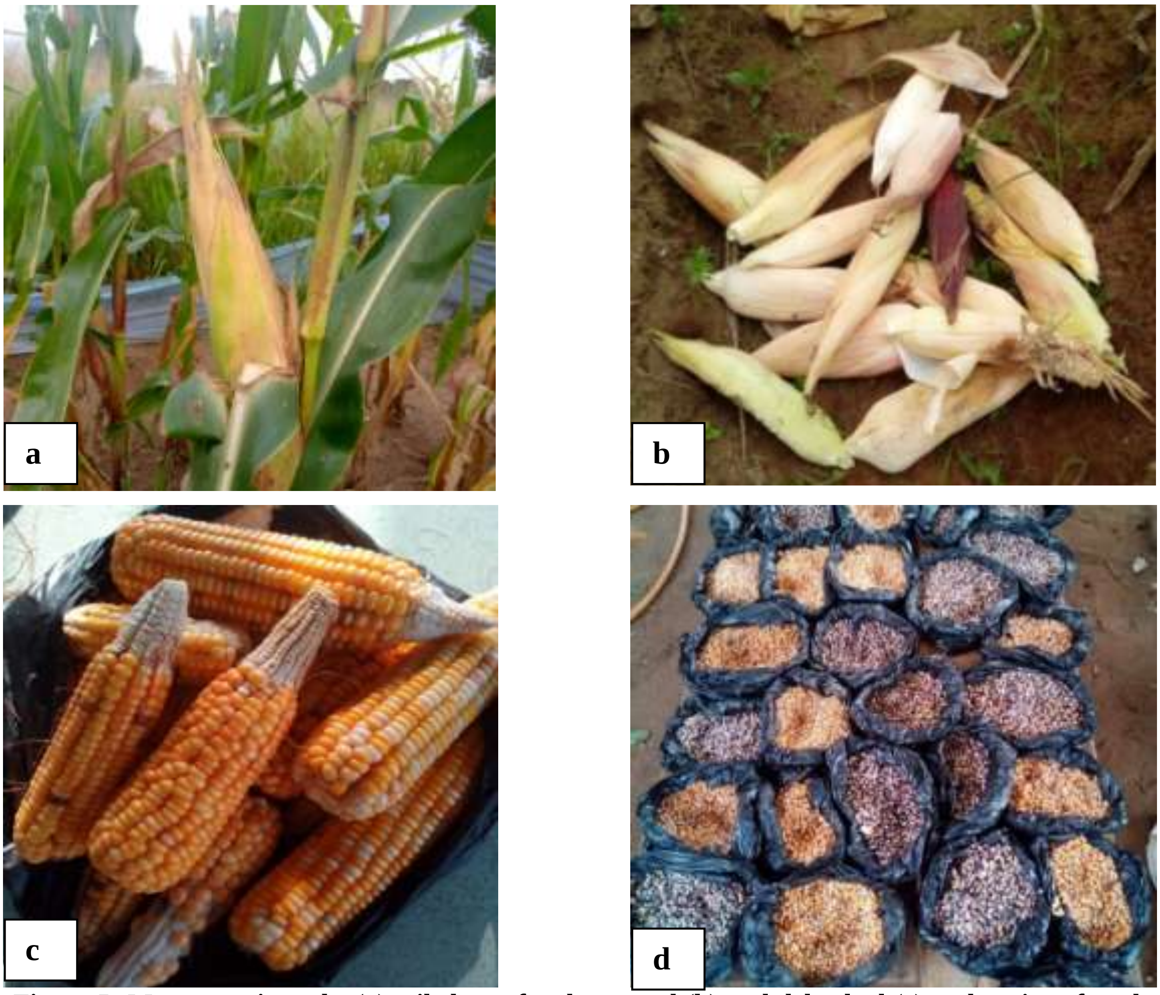

Figure 5: Mature maize cobs (a), piled up after harvested (b) and dehusked (c) and grains after draining (d)

Measuring parameters

In this study five growth parameters (width, length and number of leaves, leaf surface and plant height), three phenological parameters (dates of staminate apparition, cob apparition and maturation) and seven yield parameters (length, width, thickness and weight of grains, number of grains per cob, weight of 100 grains) were evaluated. Leaf surface (LeSu) was calculated following Bonhomme (1982)'s formula for maize LeSu = length × width × 0.75.

Statistical analyses

All data collected in this study were statistically analyzed using SAS statistical software (SAS, 2004). Percentage data were arcsin-transformed before analysis (Little, 1985) but untransformed data were used to calculate means to present the results. Analysis of variance with three classification criteria (ANOVA 3) was performed to test individual then combined effect of the studied factors (maize variety, sowing practice and weed control method). When the null hypothesis was rejected for each parameter, multiple comparisons using the Least Significant Difference (LSD) were carried out test to separate the means (Dagnélie, 1998). All the tests were performed at $\alpha = 0.05$ significance level.

RESULTS AND DISCUSSION

Results

Effect of sowing practice on the growth of both maize varieties

Values of maize plants growth parameters following sowing practice for both varieties (yellow and purple) are reported in Table 1. ANOVA results of these values revealed that globally, all maize plants regularly grew from the first to the seventh week after sowing (WAS) in both varieties. In yellow variety, for flat sowing, plants showed an increase in height (from 9.21 to 121.86 cm), leaf number (from 5.02 à 12.15 leafs / plant) and dimensions (length from 15.14 to 66.84 cm, width from 2.18 to 8.76 cm and surface from 25.96 to 444.45 cm^2). Comparison of both sowing practices revealed that plant growth was more important on slope than on flat in this variety. Besides, at the seventh WAS, contrary to the flat sowing, the slope sowing improved plant height (135.28 against 121.36 cm), leaf number (12.52 against 11.68 / plant) and dimensions (length 72.42 against 66.84 cm, width 11.46 *versus* 8.76 cm and surface 577.03 *versus* 444.45 cm^2). The same tendencies were obtained in purple cultivar.

Slope being the best sowing practice, comparison of both cultivars at the 7^{th} WAS for this practice indicated that the yellow cultivar produced more higher plant (135.28 *versus* 127.97 cm) carrying longer (72.42 cm against 67.18 cm), wider (11.46 cm against 8.94 cm) and spread (577.03 cm^2 *versus* 557.62 cm^2) leafs than the purple ones.

Slope sowing improves plant growth through stem height, leaf number and size in both maize varieties (yellow and purple). Nevertheless, the yellow cultivar grew faster than the purple one.

Table 1: Evolution of plant growth parameters in both maize varieties (yellow and purple) following sowing practice

Sowing Factors		Cropping time	Plant height (cm)	Leafs			
				Number / plant	Length (cm)	Spread (cm)	Surface (cm^2)
Yellow variety	Slope	1 WAS[1]	8.38±0.14^{h}	5.20±0.06^{h}	14.54±0.23^{h}	2.02±0.02^{e}	22.60±0.50^{f}
		2 WAS	15.99±0.30^{g}	6.99±0.08^{g}	17.43±0.27^{c}	2.13±0.03^{e}	29.97±0.81^{f}
		3 WAS	39.55±0.78^{d}	9.53±0.10^{c}	40.75±0.46^{g}	5.61±0.05^{d}	173.65±2.87^{d}
		4 WAS	68.51±1.18^{f}	11.74±0.10^{f}	54.63±0.51f	7.39±0.04^{bc}	301.60±3.15^{c}
		5 WAS	88.16±1.63^{e}	14.07±0.97^{e}	66.45±0.54^{e}	10.39±0.35^{a}	573.71±89.95a
		6 WAS	135.28±2.11^{a}	12.52±0.14^{b}	72.42±0.47^{a}	11.46±1.81^{a}	577.03±24.28^{b}
	Flat	1 WAS	9.21±0.15^{h}	5.42±0.07^{f}	15.14±0.24^{h}	2.18±0.02^{e}	25.98±0.60^{f}
		2 WAS	18.89±032^{g}	8.47±0.64^{b}	23.00±0.31^{b}	3.33±0.08^{e}	61.17±1.64^{f}
		3 WAS	43.30±0.81^{c}	10.05±0.09^{ed}	40.75±0.45^{g}	5.48±0.04^{d}	169.67±2.59^{d}
		4 WAS	67.05±0.97^{f}	10.83±0.10^{e}	54.69±0.53^{f}	6.37±0.04^{bd}	261.43±9.07^{c}
		5 WAS	91.26±1.68^{e}	12.15±0.12^{h}	68.04±0.56^{d}	8.23±0.05^{c}	422.39±4.79^{b}
		6 WAS	121.86±1.89^{b}	11.68±0.11^{h}	66.84±0.49^{de}	8.78±0.05^{c}	444.55±4.72^{a}
Purple variety	Slope	1 WAS	7.35±0.11^{j}	5.02±0.06^{c}	14.16±0.23^{j}	1.80±0.03^{j}	19.24±0.44^{i}
		2 WAS	13.94±0.26^{h}	7.25±0.08^{bc}	21.84±0.25^{h}	2.64±0.03^{h}	44.38±0.86^{f}
		3 WAS	37.21±0.73^{f}	9.34±0.09^{bcde}	38.21±0.48^{f}	4.87±0.05^{f}	145.36±2.71^{d}
		4 WAS	65.44±1.09^{i}	11.71±0.11^{bde}	51.19±0.48^{d}	5.92±0.03i	228.17±2.71^{h}
		5 WAS	84.51±1.75^{c}	12.99±0.13^{de}	62.85±0.53b	8.50±0.05^{d}	402.57±4.48^{a}
		6 WAS	127.97±1.89^{b}	12.73±0.14^{ae}	67.18±0.61^{i}	8.94±0.05^{b}	457.62±5.68^{g}
	Flat	1 WAS	8.06±0.26j	5.34±0.07^{c}	15.18±0.24j	1.72±0.01^{j}	19.89±0.40^{i}
		2 WAS	17.98±0.26^{g}	7.75±0.06^{bcd}	23.84±0.29^{g}	3.50±0.03^{g}	65.48±1.24^{e}
		3 WAS	42.34±0.60^{e}	10.03±0.07^{bde}	39.68±0.50^{e}	5.22±0.05^{e}	159.79±2.87^{c}
		4 WAS	66.81±0.75i	12.09±0.10^{de}	52.78±0.49^{c}	5.90±0.04i	232.88±2.76^{h}
		5 WAS	92.30±1.59^{b}	12.18±0.14^{e}	61.49±0.47^{a}	8.18±0.05^{c}	377.55±3.83^{b}
		6 WAS	122.88±1.59^{a}	17.47±5.74^{e}	66.20±0.53i	9.24±0.25^{a}	464.70±13.48^{g}
Statistics[2]		***F***	14.64	6.044	32.3	4.18	3.920
		P	<0.001	<0.001	<0.001	<0.001	<0.001

[1]*WAS weeks after sowing*
[2]*In each row, values with the same superscript letter are not significantly different from each over (ANOVA, P > 0.05)*

Effect of weeding methods on the growth of both maize varieties

Table 2 presented values of maize plants growth parameters following weeding methods for both varieties (yellow and purple). ANOVA results of these values revealed that globally, all maize plants regularly grew from the first to the seventh week after sowing (WAS) in both varieties for each weeding method (manual, chemical and control). For example in purple variety, for control treatment (unweeding), plants expressed an increase in height (from 7.74 to 118.93 cm), leaf number (from 5.35 à 10.60 leafs / plant) and dimensions (length from 14.08 to 60.32 cm, width from 1.70 to 8.07 cm and surface from 18.21 to 366.33 cm^2). Compared to this control (unweeding), both manual and chemical weeding methods improved maize plants growth. Besides, at the seventh WAS, contrary to the control (unweeding), manual and chemical weeding improved respectively plant height (129.34 and 127.79 cm against 118.93 cm), leaf number (13.08 and 12.95 against 10.60 / plant) and dimensions (length 67.71 and 74.51 cm against 60.32 cm, width 10.21 and 9.55 cm *versus* 8.07 cm and surface

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Table 2: Evolution of plant growth parameters in both maize varieties (yellow and purple) following weeding methods

Weeding methods		Cropping time	Plant height	Leafs			
				Number/ plant	Length (cm)	Width (cm)	Surface (cm^2)
Yellow	Chemical	1 WAS[1]	8.42±0.19^{m}	5.28±0.08^{p}	14.47 ±0.29^{s}	2.03±0.03^{mnop}	22.79 ± 0.64^{m}
		2 WAS	17.89±0.36^{l}	8.90±0.95^{m}	19.50 ± 0.40^{r}	2.54±0.05 ^{mnop}	41.68 ± 1.59^{m}
		3 WAS	42.71±0.77^{j}	9.84±0.10^{l}	41.52 ± 0.57^{l}	5.20 ± 0.0^{5kl}	162.18 ± 2.88^{kl}
		4 WAS	67.64±1.25^{hi}	10.94±0.13^{ij}	56.15 ± 0.66^{gh}	7.13 ± 0.05^{ghi}	298.80 ± 4.06^{gh}
		5 WAS	93.13±1.89^{f}	12.38±0.17^{cdef}	67.17 ± 0.71^{c}	8.82 ± 0.06^{cde}	444.11 ± 5.64^{d}
		6 WAS	133.02±2.54^{a}	12.74±0.13^{bcd}	73.39 ± 0.56^{a}	9.84 ± 0.24^{bc}	538.28± 12.19^{bc}
	Manual	1 WAS	8.75 ±0.15^{m}	5.21±0.10^{p}	15.16 ± 0.31^{s}	2.14 ± 0.03 ^{mnop}	24.97 ± 0.71^{m}
		2 WAS	17.36±0.40^{l}	7.43±0.10^{no}	21.04 ±0.41^{q}	2.97 ± 0.13 ^{mnop}	51.60 ± 2.26^{m}
		3 WAS	39.50±1.14^{jk}	10.10±0.10^{hij}	39.26 ± 0.51^{m}	5.94 ± 0.06^{ijkl}	176.29 ± 3.35^{jkl}
		4 WAS	66.79±1.38^{hi}	11.27±0.14g^{hij}	53.02 ± 0.66^{j}	7.07 ± 0.05^{ghij}	279.99 ± 3.79^{ghi}
		5 WAS	83.58±1.66^{g}	12.61±0.18^{bcd}e	69.79 ± 0.71^{b}	10.78 ± 0.48^{b}	597.53±34.49^{ab}
		6 WAS	128.71±2.62^{b}	13.90±0.43^{a}	71.19 ± 0.61^{b}	12.65 ± 2.73 ^{a}	653.82±134.97^{a}
	Control (unweeded)	1 WAS	9.23±0.21^{m}	5.45±0.08^{p}	14.91 ± 0.28^{s}	2.15 ± 0.03 ^{mnop}	25.15 ± 0.70^{m}
		2 WAS	17.09±0.46^{l}	6.86±0.12^{o}	20.14 ± 0.34^{qr}	2.71 ± 0.04 ^{mnop}	43.65 ± 1.20^{m}
		3 WAS	42.01±1.03^{jk}	9.45±0.15^{lm}	41.44 ± 0.59^{l}	5.54 ± 0.06 ^{mnop}	176.73 ± 3.76^{jkl}
		4 WAS	68.97±1.36^{h}	11.69±0.12^{fgh}	54.78 ± 0.61^{hi}	6.44 ± 0.05^{hijk}	264.95 ± 3.75^{ghi}
		5 WAS	92.50±2.42^{f}	12.02±0.15^{def}	64.80 ± 0.60^{d}	8.07 ± 0.07^{efg}	396.19 ± 5.60^{de}
		6 WAS	123.75±2.38^{c}	10.95±0.11^{hij}	64.21 ± 0.58^{de}	8.14 ± 0.06^{efg}	395.10 ± 4.87^{de}
Purple	Chemical	1 WAS	8.07±0.15^{m}	5.26±0.09^{p}	14.78 ± 0.30^{s}	1.83 ± 0.02^{nop}	20.77 ± 0.57^{m}
		2 WAS	15.77±0.33^{l}	7.67±0.08^{n}	22.89 ± 0.33^{p}	3.00 ± 0.05^{mno}	52.75 ± 1.26^{m}
		3 WAS	40.28±0.82^{jk}	9.67±0.09^{l}	41.02 ± 0.55^{l}	5.01 ± 0.06^{l}	157.24 ± 3.09^{l}
		4 WAS	66.91±1.12^{hi}	11.94±0.12^{efg}	53.82 ± 0.55^{ij}	5.94 ± 0.05^{ijkl}	239.73 ± 3.10^{hij}
		5 WAS	83.66±1.40^{g}	13.17±0.14^{bc}	62.86 ± 0.56^{e}	8.35 ± 0.06^{defg}	393.19 ± 4.57^{de}
		6 WAS	127.79±2.20^{b}	12.95±0.13^{bc}	74.51 ± 0.63^{a}	9.55 ± 0.05^{bcd}	517.98 ± 19.11^{c}
	Manual	1 WAS	7.32±0.13^{m}	4.95±0.07^{p}	15.17 ± 0.31^{s}	1.76 ± 0.04^{op}	19.74 ± 0.54^{m}
		2 WAS	15.92±0.39^{l}	7.49±0.10^{no}	24.60 ± 0.33^{o}	3.19 ± 0.05^{m}	60.33 ± 1.41^{m}
		3 WAS	38.83 ±0.89^{k}	9.80±0.12^{l}	38.92 ± 0.65^{m}	5.11 ± 0.06^{l}	152.16 ± 3.40^{l}
		4 WAS	66.76±1.07^{hi}	12.10±0.11^{def}	50.68 ± 0.58^{k}	5.98 ± 0.05^{ijkl}	226.18 ± 3.11^{ijk}
		5 WAS	81.43±1.70^{g}	13.31±0.16^{ab}	63.28 ± 0.68^{e}	8.60 ± 0.06^{cdef}	409.87 ± 5.68^{de}
		6 WAS	129.34±2.08^{ab}	13.08±0.15^{bc}	67.71 ± 0.61^{c}	10.21 ± 0.37^{b}	534.17 ± 5.30^{bc}
	Control (unweeded)	1 WAS	7.74±0.17^{m}	5.35±0.08^{p}	14.08 ± 0.28^{s}	1.70 ± 0.02^{b}	18.21 ± 0.45^{m}
		2 WAS	16.19±0.38^{l}	7.35±0.10^{no}	21.01 ± 0.35^{qr}	3.05 ± 0.06^{mn}	51.63 ± 1.48^{m}
		3 WAS	40.27±0.87^{jk}	9.61±0.11^{lm}	36.88 ± 0.61^{n}	5.03 ± 0.08^{l}	148.41 ± 3.82^{l}
		4 WAS	64.64±1.28^{i}	11.67±0.17^{fgh}i	51.44 ± 0.66^{k}	5.81 ± 0.06^{kl}	225.40 ± 3.82^{ijk}
		5 WAS	100.61±2.58^{e}	11.24±0.15^{ghij}	57.37 ± 0.63^{g}	7.48 ± 0.06^{fgh}	325.81 ± 4.99^{fg}
		6 WAS	118.93±2.06^{d}	10.60±0.11^{jk}	60.32 ± 0.60^{f}	8.07 ± 0.06^{efg}	366.33 ± 4.91^{ef}
Statistics[2]		*F*	4.21	2.92	5.10	1.99	2.17
		P	< 0.001	< 0.001	< 0.001	0.040	0.010

[1]*WAS weeks after sowing*
[2]*In each row, values with the same superscript letter are not significantly different from each over (ANOVA, P > 0.05)*

534.17 and 517.97 cm^2 *versus* 366.33 cm^2). Comparison of both weeding methods revealed that manual weeding provided higher plant (129.34 against 127.79 cm) carrying more (13.08 against 12.95 leafs / plant) and shorter (67.71 versus 74.51 cm), wider (10.21 versus 9.55 cm) and spread (534.17 and 517.97 cm^2) leafs than the chemical one. Yellow cultivar exhibited the same tendencies and did not show significant difference with the purple cultivar.

Weeding improves plant growth through stem height, leaf number and size in both maize varieties (yellow and purple). Moreover, manual weeding accelerates plants growth more than chemical one in both varieties.

Combined effects of sowing practice and weeding methods on plant phenology, yield and yield parameters in both maize varieties

Effects on maize plants phenology

Values of both maize varieties (yellow and purple) plants phenological parameters following sowing practice and weeding methods are reported in Table 3. ANOVA results of these values revealed that a part from the date of stamens apparition that is not affected, sowing practices and weeding methods significantly influenced the dates of cob apparition and their maturation in both varieties.

In yellow cultivar, the maize plant weeding method influenced the dates of cob apparition and maturation following sowing practice. Indeed, for slope sowing, manual and chemical weeding respectively shortened the cob appearance time from 59.44 days to 57.77 and 54.00 days after sowing (DAS) and their maturation from 72.84 to 70.66 and 67.13 DAS. In contrast, for flat sowing, manual and chemical weeding did not affect the cobs phenology, which respectively appeared (57.73, 56.92 and 57.53 days) and matured (70.20; 70.21 and 70.61 days) all at the same time as the control.

In purple cultivar, the maize plant weeding method influenced the dates of cob apparition and maturation following sowing practice. For slope sowing, manual and chemical weeding respectively shortened the cob appearance time from 59.44 days to 57.77 and 54.00 days after sowing (DAS) and their maturation from 72.84 to 70.66 and 67.13 DAS. Flat sowing expressed the same tendencies. Comparison of both sowing practices revealed that they did not affect these phenological parameters in purple and yellow cultivars.

In sum, plant phenology of both maize varieties (purple and yellow) was affected through shortening of cob apparition and maturation only by weeding method (manual and chemical) not by sowing practices (flat or slope).

Table 3: Variation of plant phenological parameters following sowing practice and weeding methods in both maize varieties (yellow and purple)

Cultural factors			**Date of stamens apparition (DAS)[1]**	**Date of cob apparition (DAS)**	**Date of cob maturation (DAS)**
Mayze variety	**Sowing practice**	**Weeding methods**			
Yellow	**Slope**	Manual	52.40 ± 0.71^{a}	57.73 ± 1.26^{abcd}	70.66 ± 1.30^{bcd}
		Chemical	50.73 ± 0.73^{a}	54.00 ± 0.86^{e}	67.13 ± 1.37^{d}
		Control	51.66 ± 0.68^{a}	59.44 ± 1.02^{ab}	72.84 ± 0.80^{abc}
	Flat	Manual	51.93 ± 0.54^{a}	57.73 ± 0.98^{abcd}	70.20 ± 0.99^{bcd}
		Chemical	50.85 ± 0.66^{a}	56.92 ± 1.02^{bcde}	70.21 ± 0.98^{bcd}
		Control	51.23 ± 0.65^{a}	57.53 ± 1.00 ^{bcde}	70.61 ± 1.04b^{cd}
Purple	**Slope**	Manual	51.73 ± 0.67^{a}	54.86 ± 1.04b^{e}	68.86 ± 1.04^{d}
		Chemical	51.33 ± 0.75^{a}	56.09 ± 1.76^{cde}	70.50 ± 2.03b^{cd}
		Control	52.84 ± 0.46^{a}	60.07 ± 0.86^{a}	72.84 ± 0.87^{ab}
	Flat	Manual	49.06 ± 0.63^{a}	54.46 ± 1.33^{e}	67.60 ± 1.87^{d}
		Chemical	51.60 ± 0.57^{a}	57.40 ± 1.22^{bcde}	70.53 ± 1.37^{bcd}
		Control	51.00 ± 0.97^{a}	61.10 ± 1.04^{a}	75.60 ± 1.24^{a}
Statistics[2]		F	0.10	4.00	6.60
		P	0.949	0.018	0.001

[1]DAS Days after sowing

[2]In each column, values with the same superscript letter are not significantly different from each over (ANOVA, P > 0.05)

Effect on maize yield and yield parameters

Values of both maize varieties (yellow and purple) cobs, grains phenological and yield parameters following sowing practice and weeding methods are mentioned in Table 4. ANOVA results of these values revealed that a part from the weigth of 100 grains that is not affected, sowing practices and weeding methods significantly influenced these parameters.

Table 4: Variation of cobs, grains morphological, yield and yield parameters following sowing practice and weeding methods in both maize varieties (yellow and purple)

Cultural factors			**Grains morphology**			**Cob weigth (g)**	**Grain yield** (kg/ ha)	**Weigth of 100 grains** (mg)
Variety	**Sowing practice**	**Weeding method**	**Lenght (mm)**	**Wide (mm)**	**Spread (mm)**			
Yellow	Slope	Chemical	10.27 ± 0.12^{e}	8.91 ± 0.12^{e}	4.74 ± 0.12^{e}	156.05 ± 20.02^{acd}	1716.67± 283.33^{b}	22.00 ± 1.34^{a}
		Manual	10.14 ± 0.11^{e}	8.78 ± 0.11^{e}	4.61 ± 0.11^{e}	190.15 ± 32.23^{a}	2266.67± 450.00^{a}	22.03 ± 0.64^{a}
		Control	8.99 ± 0.11^{d}	7.63 ± 0.11^{d}	3.46 ± 0.11^{d}	66.18 ± 12.18^{be}	600.00 ± 100.00^{h}	20.17 ± 1.79^{a}
	Flat	Chemical	9.98 ±0.18b^{b}	8.62 ± 0.18^{b}	4.45 ± 0.18^{be}	113.47±18.26^{cde}	1383.33±216.67^{ef}	20.43 ± 1.89^{a}
		Manual	9.53 ± 0.16^{c}	8.17 ± 0.16^{c}	4.00 ± 0.16^{c}	106.06 ± 23.09^{bde}	1216.67± 233.33^{f}	17.97 ± 0.47^{a}
		Control	9.07 ± 0.10^{d}	7.71 ± 0.10^{d}	3.54 ± 0.10^{d}	70.06 ± 15.86^{be}	766.67± 200.00^{gh}	18.40 ± 0.15^{a}
Purple	Slope	Chemical	10.18 ± 0.10^{e}	8.82 ± 0.10^{e}	4.65 ± 0.10^{e}	173.89 ± 41.06^{ac}	2050.00± 600.00^{b}	23.53 ± 2.37^{a}
		Manual	10.90 ± 0.10^{a}	9.54 ± 0.10^{e}	5.37 ± 0.10^{a}	160.06 ± 23.05^{acd}	2050.00± 283.33^{b}	22.40 ± 1.15^{a}
		Control	8.77 ± 0.11^{d}	7.41 ± 0.11^{d}	3.24 ± 0.11^{d}	60.32 ± 15.08^{be}	600.00 ± 133.33^{h}	18.63 ± 0.87^{a}
	Flat	Chemical	9.64 ± 0.19^{bc}	8.28 ± 0.19^{bc}	4.11±0.19^{bc}	120.00 ± 15.03^{abce}	1433.33±233.33^{de}	19.90 ± 0.01^{a}
		Manual	9.91± 0.17^{bce}	8.55± 0.17^{bce}	4.38± 0.17^{bce}	123.25 ± 16.09^{abe}	1500.00±250.00^{cd}	21.97 ± 0.34^{a}
		Control	8.86 ± 0.15^{d}	7.50 ± 0.15^{d}	3.33 ± 0.15^{d}	46.65 ± 3.00^{b}	550.00 ± 50.00^{h}	19.07 ± 1.33^{a}
Statistics		*F*	95.47	88.31	27.89	14.5	17.25	1.403
		P	<0.001	<0.001	<0.001	0.003	< 0.001	0.2653

In purple variety, transition of sowing practice from flat to slope enhance cobs weight (from 160.60 to 123.25 g), grains size (length from 9.91 to 10.90 mm, wide from 8.55 to 9.54 mm and spread from 4.11 to 4.38 mm) and yield (from 1500 to 2050 Kg/ ha) when plants were manually weeded. Furthermore, for each sowing practice (flat or slope) in this variety, weeding maize plant improved these parameters. For example, with flat sowing, manual and chemical weeding improved respectively cobs weight (from 46.65 to 123.25 g and 120.00 g), grains size (length from 8.86 to 9.91 mm and 9.64 mm, wide from 7.50 to 8.55 mm and 8.28 mm and spread from 3.33 to 4.38 mm and 4.11 mm) and yield (from 550 to 1500 Kg/ ha and 1433 Kg/ ha). The same tendencies were obtained for slope sowing as well as for yellow variety.
The best performances (heaviest cobs carrying biggest grains leading to highest yield) were obtained with slope sowing and manual weeding followed by chemical one in both varieties. In addition, these performances, yellow variety more yielded (2266.67 Kg/ ha) than the purple one (2050.00 Kg / ha).

Discussion
The success of any crop depends not only on the quality of sown seed but also on the technical itinerary followed (Lamichhane and Solatini, 2020). In this study, the effects of sowing practice and weed control method on growth and yield parameters were analyzed for both maize varieties (purple and yellow) in order to propose a technical itinerary that could improve their yield. This study showed that both factors (sowing practice and weeding method), individually or combined, influenced these parameters.
Sowing practice considerably influenced the plant growth and yield of both maize varieties tested. Compared to the flat sowing, ploughing (slope sowing) improved maize plant height, leaf number and size of both maize varieties during cropping. This growth improvement by slope sowing could be explained by the very important role that played by plowing in soil physical properties enhancement through its aeration and water retention capacity and looseness for root penetration (Yao-Kouamé and Allou, 2008). Improvement of both maize varieties plants root system would affect their weight, length and surface area, as well as their distribution in the soil. Deep in the soil and well developed, these roots could have well extracted nutrients for the plant. This could explain why maize plant growth was higher with slope than with flat. This finding supports Karuma's (2016) results. Indeed, evaluating the effect of sowing technique on cotton and maize yields, this researcher noted that growth and yields were higher with slope (tillage) than with flat sowing. Furthermore, Chen and Weil (2011), Wlaiwan and Jayasuriya (2013) found that only roots are able to explore the soil's available water and nutrients to sufficiently feed the plant, and can consequently affect crop yield in maize. Therefore, soil tillage, through the slope sowing, is believed to provide plants with essential nutrients through an efficient root system for their growth and yield. According to Dayou *et al*. (2017), simplifying cultivation technique of "zero ploughing" through direct sowing on flat, results in severe soil compactness problems. This could lead to lower soil porosity and less available water for plants, as well as roots inability to deeply penetrate this compacted soil in quest of water and nutrients, resulting in reduced plant yield. Wlkowski *et al.* (2008) reported that soil compaction that leads to its aeration decrease and rise of its resistance to root penetration, can reduce crop yields by up to 50%.
Beyond sowing practice, weed control methods also affected plant growth, phenology and yield of both maize varieties (purple and yellow) during this study. Compared to controls (unweeded), the manually and chemically weeded plants achieved the best agronomic performances (growth, phenology and yield). These results could be explained by the cancellation of competition between interest plants (maize) and other weeds for the soil nutrients available in the weeded plots. Weed-free maize plants could therefore have fully benefited from all available nutrients within soil solution for their successful growth via height, leaf number, size and foliar area; resulting in the shortening of their blossoming and maturation time. These findings corroborate Gantoli *et al*'s (2013) who showed that competition in the early stages of cultivation is more severe than in the developmental stages. According to these researchers, weeds uptake nutrients faster than the interest crop. Khan *et al.* (2009) also reported that cultural practices especially weed control, shorten flowering and maturation times in maize. The poor performance of maize control plants (under permanent weed) which produced the smallest cobs clearly attests to the harmful effect of weeds. Peña-Asin *et al*. (2013) also reported a similar decline in maize plant performance through low yield. According to these scientists, maize crop invasion by weeds is one of the major and recurrent problems of agriculture. In fact, weeds compete with the desired plant, suffocate it and deplete the soil water and nutrients. They cause significant damage, one of which is competition for water is more acute. According to Mukhtar and Eneminyene (2018), without restrictions (weed control), weed competition with maize can result in yield reductions of 46-54% in maize.

Both sowing practice and weeding method considerably affected maize plants growth and yield in both yellow and purple varieties. The good performances (heavy cobs carrying bigger grains leading to high yield) were obtained with slope sowing and manual weeding followed by chemical one in both varieties. These results can have two explanations. First, plowing through slope sowing improved soil physical properties through its aeration and water retention capacity and looseness for root penetration (Yao-Kouamé and Allou, 2008). Second, the cancellation of competition between interest plants (maize) and other weeds for the soil nutrients available in the weeded plots. This may had therefore allowed plants to fully benefice from all available nutrients for their successful growth via height, leaf number, size and foliar area; resulting in good yield. Lamichhane and Soltani (2020) obtained similar results for maize. Although these performances, yellow variety provided the highest yield (2266.67 Kg/ ha) compared to the purple one (2050.00 Kg/ ha). Yellow variety being an improved one provided by an Ivorian research center (CNRA) to maize farmers, it is well adapted to the new environmental and climate changes than the traditional purple (Kouakou et al., 2010). Abera *et al*. (2017) reported similar results after introduction of new maize hybrid varieties in Ethiopia.

CONCLUSION

This study showed that both sowing practice and weed control method affected plant growth, phenology and yield of both tested maize varieties (yellow and purple). During cropping, slope sowing improved plant growth via height, leaf emission and expansion. Phenologically, it shortened flowering and maturation time. At harvest, it favored cob weight and size, grain content and grain yield in both maize varieties suggesting that both maize varieties should be grown on slope.

Weeding, manually or chemically, improved growth of maize plants through their height, leaf number and area in both studied varieties leading to their good yield. However, manual weeding provided the higher yields in both maize varieties. While slightly less effective than the manual weeding, the chemical weeding requires less effort, labor, and equipment, which allows faster expansion of planted areas. Nevertheless, considering the active principles found in some herbicides, like triazines and atrazine that can pollute groundwater, manual weeding, if not mechanical or trailed should be preferred.

Despite the relatively lower yield of purple variety compared to yellow one, its cultivation should be encouraged through flat sowing and manual or mechanical weeding due to its endemic character.

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Conflicts of Interest

All authors declare that they have no conflicts of interest regarding the publication of this paper.

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