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Impact of Manual Weeding Frequency on Dry Grain Yield of Maize (*Zea mays* L) Under the Soil and Climate Conditions of Ngandajika, Case Study of the MPOYI Group (Lomami, DR Congo)

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Abstract

In Ngandajika (Democratic Republic of Congo), farmers still prefer to grow local varieties, accusing improved varieties of being susceptible to disease, demanding nutrients, and requiring excessive labor. They also criticize these varieties for having large rachises and few grains, requiring labor-intensive shelling, without considering several advantages offered by different improved varieties, such as earliness, yield, and the quality of by-products, including flour consistency. Local varieties are less productive (yield less than 1 ton of maize grain/ha) than improved varieties, whose production exceeds 1.9t/ha when manually weeded and hoed three times, namely 15, 30, and 45 days after sowing. In the strategy to increase the yield of maize cultivation, the Musangana variety, which is one of the most cultivated varieties, was chosen and the impact of the frequency of manual weeding on the growth and dry grain yield of maize during the 2021-2022 growing season was evaluated; the trial was conducted in the open field at the MPOYI group under a Latin square design comprising four complete random blocks and comprising 4 elementary plots representing the experimental treatments. The treatments consisted of (T0) treatment not receiving weeding, (T1) treatment receiving weeding once, (T2) treatment receiving weeding twice and (T3) treatment receiving weeding three times. The results show a higher yield (1.9t/ha) of dry grains of maize with manual weeding having received weeding three times during the entire growing cycle, followed by 1.5t/ha obtained with those of manual weeding having received weeding twice during the entire growing cycle and 1.1t/ha with manual weeding having received weeding once during the growing cycle. The lowest average is 0.3t/ha on the manual weeding not having received weeding during the entire growing cycle.

Keywords: Maize, Musangana Variety, Manual Weeding, Hoeing, Dry Fruit Yield, Mpoyi Group, Ngandajika territory.

1. INTRODUCTION

Maize (*Zea mays* L) is one of the three most widely cultivated cereals in the world. It ranks third among food crops after cassava and plantains (Nyembo, 2010; Faostat, 2018). It is cultivated not only for human and animal food but also for numerous industrial uses. However, food availability is characterized by shortages for a large part of the population, thus becoming dependent on imports from southern Africa (Nyembo *et al*., 2014). Despite its importance, its production is due to low yields, a consequence of poor farming practices (Useni *et al*., 2014) and the use of unimproved seeds (Nyembo, 2010). This situation creates significant food insecurity despite the country's immense agricultural potential (Huart *et al*., 2007).

However, this strategy is controversial as these imports absorb a significant portion of the country's foreign exchange while their export earnings are often very fragile (Temple and Moustier, 2004). Therefore, in order to break this dependence on food stocks of maize in the DRC, it will be necessary to increase national production with innovative technologies in agriculture. The DRC is a country in the sub-Saharan region where agriculture is the sector that employs more or less 70% of the population, although it contributes little to the gross domestic product (Mulimbi *et al*., 2019). Kasongo, (2008), reports that agricultural production is dominated by peasant agriculture.

Despite the place occupied by this commodity in the agrarian system of this province (Useni *et al*, 2013). This deficit is generally filled by imports from southern Africa (Useni *et al*., 2014). Yields vary from one region to another in the Democratic Republic of Congo, but the national average is 0.8 to 1 t/ha and the latter is too low compared to those of countries such as Italy 9,530 kg/ha, Canada 6,630 kg/ha, China 4,570 kg/ha (Talue *et al*. 2009) this is partly due to the use of improved varieties and various pests and poor cultural practices (Senasem, 2008). As for this scourge, the increase in yield through the improvement of cultural practices (Kouadio, 2003; Melendez et *al*., 2008; Roose *et al*., 2008), the contribution of mineral fertilizers (Ganry et *al*., 2000; Jama *et al*., 2000; Harmand and ballé, 2001; Kaho *et al*., 2012; Useni *et al*., 2012) are important.

However, these solutions have an impact that is unbearable for subsistence farmers (Kasongo *et al*., 2013). In the current situation in Lomami Province in general and more specifically in Ngandajika Territory, late weeding and failure to comply with weeding frequency are among the major constraints in maize cultivation. This study will highlight the most suitable and high-yielding weeding method for effective weed management in maize cultivation, in the soil and climate conditions of Ngandajika Territory.

The overall objective of this study is to assess the influence of manual weeding with a hoe, also known as hoeing, on maize yield in the MPOYI group in Ngandajika Territory.

2. MATERIALS AND METHODS

Experimental Site

This study was conducted during the growing season from August 20 to December 30, 2022, in the MPOYI group, an entity located 10 km from the town center of Ngandajika territory. The site is located at 6°769'.751" South latitude and 23°990'.872" East longitude, at an average altitude of 771 m.

Plant Material

Regarding the plant material, we used seeds of the improved Musangana maize variety from INERA/Ngandajika.

Method

In this study, we used the hypothetico-deductive method combined with documentary techniques, experimentation, observation, sampling, and statistics. On a practical level, we used the following techniques:

Site Selection

The experimental site was located in the MPOYI group, approximately 10 km from Ngandajika town center. The MPOYI plot had previously been cultivated with cowpeas in the 2022 B season. The dominant vegetation consisted of *Tripsacum laxum, Ageratum conyzoides, Ageratum houstonianum, Euphorbia hirta, Imperata cylindrica, Commeline benghalensis, Setaria sphacelata, Hyparrhenia diplandra, Euphorbia heterophylla,* and *Panicum maximum*. The experimental plot showed no slope at the base, reflecting the influence of a fertility gradient

Site Preparation

Our experimental plot was demarcated based on the Pythagorean Theorem, and then we cleared the land, followed by plowing, and then the soil was crumbled with a hand hoe. The delimitation of the experimental plots was carried out according to our experimental device using the sowing rope and the measuring tape; then the rest of the work was carried out according to our test protocol.

Experimental Design and Trial Conduct

Our trial was conducted in open fields from August to December 2022, using a Latin square design consisting of four complete randomized blocks. Each experimental block measured 13.5m x 4m, or 54m², comprising four elementary plots measuring 4m x 3m, or 12m² each, constituting experimental units spaced 50cm apart within the same block and 1m between different blocks. The sown area was separated from the remaining vegetation by 4m; this constituted the surroundings or edges, and measured 19m in length and 13.5m in width, or 256.5m².

Legend:

T0: The treatment that did not receive manual weeding throughout the growing cycle;
T1: Treatment that received manual weeding once during the entire growing cycle;
T2: Treatment that received manual weeding twice during the entire growing cycle;
T3: Treatment that received manual weeding three times during the entire growing cycle.

Treatment Application

The different treatments used in our experiment were randomly assigned to four randomized complete or casual blocks according to probability and permutation standards (MORILLON, 1998; AVNER Bar-Hen, 2001). These treatments were respectively composed of:

T0: The treatment that did not receive manual weeding throughout the growing cycle;
T1: The treatment that received manual weeding once throughout the growing cycle;
T2: The treatment that received manual weeding twice throughout the growing cycle;
T3: The treatment that received manual weeding three times throughout the growing cycle.

This allocation was carried out based on randomization, i.e., the technique of assigning treatments, or factors to be tested, to experimental units in accordance with defined distributions or probabilities.

This is randomization in its strict technical sense, which guarantees the elimination of systematic errors and the purely random nature of any persistent error in the observations. From this, a valid estimate of random fluctuations can be made, essential for testing the significance of real differences. Thanks to randomization, each experimental unit will have an equal chance of receiving any treatment (KIATOKO, 2015).

Sowing

The corn was sown on 08/20/2022 at a depth of approximately 3 cm from the soil for this crop. Three corn grains were sown per pocket, at a spacing of 75 cm x 50 cm. The first and last rows of sowing were 37.5 cm on either side of the edges of each experimental unit. Each experimental plot received a total of 96 corn grains.

Seedling Selection by Thinning

Vigorous plants were selected 10 days after sowing by thinning down to two plants per pocket.

Crop Care

Regarding maintenance, we carried out weeding and hoeing at different frequencies, which constituted our experimental treatments for manual weeding of cultural control. These were carried out respectively at (15, 30, and 45 days after sowing) and were regularly accompanied by hoeing to facilitate water and air circulation to allow good crop growth.

A month and a half after sowing, we earthed up the plants to strengthen them, protect them from lodging, and also facilitate their mineral nutrition. During the cultivation of our experimental site, we determined the floristic composition, and the list of weeds recorded is presented in Table 1.

Table 1: List of weeds found on the experimental site

Asteraceae	GENRES
	Ageratum conyzoïdes
	Ageratum houstonianum
	Cynedrella nodiflora
	Galisonga ciliata
	Taraxacum officinale
	Lactuca spp
	Arctium lappa
	Bidens pilosa
	Artemisia spp
	Bidens oligoflora
Poaceae	*Eleusine indica*
	Imperata cylindrica
	Sorghum halepense
	Dactylonctenium aegyptium
	Echinochloa colona
	Cynodon dactylon
	Sporobolus pyramidalis
	Tripsacum laxum
	Hyparrhenia diplandra
Cyperaceae	*Cyperus rotundus*
	Carex hirta
	Cyperus difformis
	Bolboschoenus maritimus
	Cyperus esculentus
	Cyperus papirus
Commelinaceae	*Commeline diffusa*
	Commeline benghalensis
Fabaceae	*Calopogonium mucunoïdes*
	Vigna unguilculata

Source: personal scientific research.

Observation Parameters

In order to effectively assess the impact of each weeding frequency on dry maize grain yield at harvest under the soil and climate conditions of the MPOYI group in Ngandajika territory, we collected data on the following parameters: Plant height at ear insertion: Using a graduated slat placed at the root collar to the tip of the last leaf, we collected data on this parameter; it measures the height of three central plants chosen at random, but taking care not to measure off-type or diseased plants.

This measurement was taken at flowering using a five-meter graduated ruler, and each measured plant had a corresponding height (H1, H2, and H3) according to the order of measurement. Their average represents the plant/plot height.

Plant Collar Diameter at Flowering:

We used a caliper placed at the collar to collect data on this parameter; it measures the collar diameter of three central plants randomly selected from the middle of the experimental plot, taking care not to measure off-type or diseased plants. This measurement was taken at flowering using a caliper, and each measured plant had a corresponding collar diameter (D1, D2, and D3) according to the order of measurement. Their average represents the collar diameter of the plant/plot.

Number of Days To 50% of Plants from Flowering: Each time 50% of the plants in an experimental plot showed the emergence of the plume, we counted the number of days from sowing to that day.

Number of Ears Harvested Per Plot: We manually counted the ears harvested from an elementary plot.

The Number of Grain Rows per Ear:

We manually counted the rows per ear at harvest. This count involved the ears of three central plants randomly selected in the middle of the experimental plot, but we were careful not to count off-type or diseased plants. This count was done at harvest, and each plant had a corresponding number of grain rows per ear (G1, G2, and G3) according to the order of measurement. Their average represents the number of grain rows per ear at harvest.

Plot Yield of Dry Corn Grains at Harvest: After drying and shelling, we weighed the dry corn grains on a standard scale.

Growth measurements were taken every morning starting at 8 a.m. The number of days to 50% male flowering was assessed at irregular intervals when at least 50% of flowering seedlings were observed in each experimental unit. Yield parameters were assessed at the end of the trial. Maize caryopses were measured (height), weighed, and shelled. Sun-dried grains to 17% moisture content were weighed to determine the net yield of maize in our trial.

Statistical Analysis

In order to assess the effect of each weeding method on dry maize grain yield under the soil and climate conditions of the Ngandajika region, the various data collected on the various observation parameters in our experimental site were subjected to analysis of variance using STATISTIX.10 software. The LSD (Least significant difference) test was used for multi-variate comparison of treatment means at the 5% probability threshold. (Gomez, K.A. and Gomez, A.A; 1984; Snedecor, 1978; loague K. & green r. E., 1991).

3. RESULTS

The results for vegetative and production parameters under observation with a view to the effect of manual weeding frequency on maize grain yield under the soil and climate conditions of the MPOYI group in Ngandajika territory are reported in Tables 2 and 3, respectively.

Table 2 presents the results for plant height, plant collar diameter, and the number of days to 50% of male flowering under the effect of manual weeding frequency on dry maize grain yield under the soil and climate conditions of the MPOYI group in Ngandajika territory.

Table 2: Presentation of the results for vegetative parameters

Variable Treatments	Plant height (in cm)	Diameter at the collar (in cm)	Nbre days of 50% male flowering
T0	41.75 D	1.0750 B	69.250 A
T1	56.00 C	1.2500 B	66.000 B
T2	75.50 B	2.2750 A	60.000 C
T3	106.25 A	2.1500 A	55.500 D
Standard deviation	5.5640	0.2072	0.9592
C.V (in %)	11.26	17.36	2.16
Average	69.875	1.6875	62.688

Key: A: Treatment that ranks first for an observation parameter;
B: Treatment that ranks second for an observation parameter;
C: Treatment that ranks third for an observation parameter;
D: Treatment that ranks fourth for an observation parameter.

In the same column for the same parameter, means followed by the same letter are not significantly different at the 5% probability level according to LSD (least significant difference). From the exploitation of the results recorded in table n°2, we note, at the significance threshold of 5% of LSD that the treatment having received manual weeding three times (T3) significantly showed a higher plant height at ear insertion (106.25 cm) and that the treatment having received manual weeding twice (T2) significantly showed a higher plant collar diameter (2.27 cm) compared to the other frequencies of manual weeding under study on our experimental site.

Regarding the number of days to 50% male flowering, the treatment that did not receive manual weeding throughout its growing cycle (T0) took many days (on average 69.2 days) to reach male flowering, and the treatment that received manual weeding three times (T3) took fewer days to reach male flowering (on average 55.5 days) compared to the other manual weeding frequencies studied at our experimental site.

Table 3 presents the results relating to the number of ears harvested, the number of grain rows/ears, and the dry maize grain treatment under the soil and climate conditions of the MPOYI group in Ngandajika territory.

Table 3: Presentation of the results on yield parameters

Variables Treatments	Nbre of ears harvested	Nbre of grain rows/ears	Drown corn grain yield (in kg/ha)
T0	8.750 D	8.500 C	0.3375 D
T1	28.750 C	14.000 B	1.1250 C
T2	33.500 B	17.500 A	1.5300 B
T3	38.750 A	18.000 A	1.9500 A
Standard deviation	1.9869	0.8165	0.1297
C.V (in %)	10.24	7.96	14.84
Average	27.438	14.500	1.2356

Key: A: Treatment that ranks first for an observation parameter;
B: Treatment that ranks second for an observation parameter;
C: Treatment that ranks third for an observation parameter
D: Treatment that ranks fourth for an observation parameter.

In the same column for the same parameter, means followed by the same letter are not significantly different at the 5% probability level according to LSD (least significant difference).

From analyzing the results recorded in Table 3, we note, at the 5% significance level of LSD, that the treatment that received manual weeding three times (T3) significantly and respectively had a high number of ears harvested per plot (an average of 38.7 ears harvested); a high number of rows of corn grains/ears (on average 18 rows of corn grains/ears) and a high yield of dry corn grains at harvest (on average 1.9 kg/plot, or 1.583 kg/ha) compared to other frequencies of manual weeding under study on our experimental site.

4. DISCUSSION

Weed management in tropical Africa has traditionally accounted for nearly 50% of agricultural production time. Weed presence causes economic losses and poses a real threat to food and nutritional security due to low yields (FAO, 2011). Annual production losses due to weeds in Africa are estimated at 2.2 million tons, costing an estimated 700 billion CFA francs (Bourgeois *et al*., 2014).

Generally, the behavior exhibited by each manual weeding frequency in maize crops under study appears to be a function of its mode of action and environmental factors. The results of the study showed that the highest dry maize grain yield was obtained with T3 (three manual weeding sessions).

The higher dry corn grain yield obtained with this weed control system could be explained by the positive effects of repeated weeding, which would consist of a considerable reduction in competition between the crop and weeds for water, minerals, and light. While in the tropics, diseases, weeds, and insects constitute one of the major agricultural problems, as control methods are scarce, the use of resistant varieties and three-time manual weeding is necessary.

This higher dry corn grain yield, resulting from this frequency of three-time manual weeding, could also be due to local variations in several ecological factors, notably rainfall and soil characteristics, which were relatively more favorable in the MPOYI group during the experiment. This difference could not be without effect given that several authors have demonstrated that a good soil potassium level leads to an increase in the vegetative components and the dry grain yield of maize (Koulibaly et *al*., 2015; Lele Nyami et *al*., 2016; Mankoussou et *al*., 2017).

Our results corroborate those of some authors who report that manual mechanical weeding with a hoe "weeding-hoeing-hilling" also gave a high yield because of the fact that in addition to controlling weeds in the field, this method of weeding improves soil structure by loosening the surface crust (Vlaar, 1992; Coulouma *et al*., 2006; Schreck, 2008; Kambire, 2016; Vanhove, 2018). Thus, we confirm our alternative hypothesis which states that: Conversely, we say that the different frequencies of weeding-hoeing or manual weeding tested in maize cultivation would not show the same performance on the ground in the MPOYI group because everything would depend on the different parameters in this case the mode of action of each frequency of weeding-hoeing; the level of implementation of cultural practices and adaptability of each frequency of weeding to the microclimate of the MPOYI group in Ngandajika territory.

Regarding average plant height, Gonzalo et *al*., 2002, indicate that this is a very important trait in variety selection because it influences lodging resistance. The higher the plant height, the more susceptible it is to lodging. The results obtained showed that the influence of manual weeding frequency more than masked that of the environment.

Information regarding plant height and plant collar diameter are respectively reported in Table 2.

These results, contained in Table 2, recall the following observations: During the rainy season A, there were significant differences (P-value <0.05) between the different frequencies of manual weeding under study on our experimental site regarding the height of the plants at the insertion of the corn ear.

On the other hand, during the same season A, the results of the analysis of variance relating to the diameter at the collar of the plants also show that there is a significant difference (P-value <0.05) between the different frequencies of manual weeding under study and that treatment T3 (treatment that received manual weeding three times) showed a significantly higher height of the plants at the insertion of the ear (106.25 cm on average).

While T2 (the treatment having received manual weeding twice) significantly showed a higher plant collar diameter (on average 2.27 cm) while treatment T1 (treatment having received manual weeding once) significantly showed a higher plant height at ear insertion (56.00 cm) while treatment T0 (treatment not having received weeding during the entire vegetative cycle) significantly showed a lower plant height at ear insertion (on average 41.7 cm) and also a lower plant collar diameter (on average 1.07 cm) compared to the other frequencies of manual weeding tested on our experimental site.

The low plant height at ear insertion and small collar diameter experienced by T0 plants could be due to strong competition for mineral elements, water, and light caused by the absence of weeding throughout the growing cycle.

The results of the analysis of variance for the number of days to 50% of male flowering (Table 2) revealed that there was a significant difference (P-value <0.05) between the differences in manual weeding under study and that the T3 treatment (treatment that received manual weeding three times) took significantly fewer days to reach male flowering and that the T0 treatment (treatment that did not receive any weeding throughout the growing cycle) took many days to reach male flowering.

This could be explained by the strong competition for water, minerals, and light experienced by corn plants that were not weeded throughout the growing cycle.

This situation could also be due to the fact that the number of days to male flowering is an important varietal characteristic that allows varieties to be classified into different categories (short cycle, medium cycle, and long cycle). The results of the analysis of variance relating to the number of ears harvested, number of rows of grains/ears and the yield of dry grains of corn at harvest (Table 3) show that there is a significant difference (P-value 0.05) between the differences in the frequencies of manual weeding under study and that treatment T3 (treatment having received manual weeding three times) significantly and respectively showed a high number of ears harvested, a high number of rows of grains/ears of corn and finally a high yield of dry grains of corn at harvest compared to the other frequencies of manual weeding tested in corn cultivation on our experimental site.

This situation could be due, as already noted, to a considerable reduction in competition between the crop and weeds caused by repeated weeding.

Compared to the yields listed in the national crop catalog for this Musangana variety in a controlled environment, i.e., 3000-4000 kg/ha, while in a farm environment for this same variety, the yields listed in the national catalog are in the order of 1000-1800 kg/ha.

Thus, the results obtained during our trial show 1.9 kg/plot (i.e., 1.583.3 kg/ha) for the T3 treatment. These results prove that the frequency of three manual weeding sessions (T3) in maize crops in the MPOYI group allowed the Musangana variety to reach the yield limits listed in the national catalog in a farm environment.

5. CONCLUSION

Our study, conducted in the MPOYI group in Ngandajika territory during growing season A of 2022 (from August 15 to December 30), focused on maize cultivation and aimed to assess the impact of each manual weeding frequency on dry maize grain yield. This study is part of the effort to improve maize production through the adoption of a weed control system leading to increased yields for producers.

Our experimental site was selected in an area where cowpea cultivation was a previous crop, and we delineated it based on the Pythagorean Theorem. On experimental ground, our trial was conducted under a Latin square design comprising four complete random blocks, each of which included (T0: treatment not receiving manual weeding during the entire growing cycle; T1: treatment receiving manual weeding once; T2: treatment receiving manual weeding twice) as experimental treatments tested on our experimental site.

The observation parameters used to collect data during the experimental period consisted of: the height of the corn plants at ear insertion, the collar diameter of the corn plants at flowering, the number of days to 50% of male flowering, the number of corn ears harvested/plot, the number of rows of grains/corn ears, and the plot yield of dry corn grains at harvest.

Analysis of variance (ANOVA) carried out at the 5% probability threshold of the data collected on the observation parameters revealed that there is a significant difference (P-value <0.05) between the different frequencies of manual weeding tested in corn cultivation with regard to all the observation parameters, in particular: the height of the corn plants at ear insertion, the collar diameter of the corn plants at flowering, the number of days to 50% of male flowering, the number of corn ears harvested/plot, the number of rows of grains/corn ears, and the plot yield of dry corn grains at harvest.

These significant differences observed especially these observation parameters listed above may be due to the interactions that prevailed between the different frequencies of manual weeding tested in corn cultivation and the environmental factors during the experimental period. For its part, the LSD (least significant difference) test carried out at the 5% probability threshold for the purpose of multiple comparison of treatment means revealed the following findings: Treatment T3: treatment having received manual weeding three times significantly showed a higher plant height at ear insertion and treatment T0: treatment not having received weeding during the entire vegetative cycle significantly showed a low plant height at ear insertion; Treatment T2: treatment having received manual weeding twice showed a significantly higher diameter at the collar of the plants at flowering and treatment T0: treatment not having received weeding during the entire growing cycle showed a significantly lower diameter at the collar of the plants at flowering;

Treatment T3:

Treatment having received manual weeding three times significantly took fewer days to reach male flowering and treatment T0: treatment not having received weeding during the entire growing cycle took significantly many days to reach male flowering; Treatment T3: treatment that received manual weeding three times significantly and respectively showed a higher plant height at ear insertion, took fewer days to reach male flowering, showed a high number of harvested ears/plot, a high number of rows of grains/ears of corn and a high yield of dry corn grains at harvest and that treatment T0: treatment that did not receive weeding during the entire vegetative cycle significantly showed a low plant height at ear insertion, a low diameter at the plant collar at flowering, took many days to reach male flowering, showed a low number of rows/ears of corn and a low yield of dry grains at harvest.

Based on the above, we note that the three-time manual weeding frequency proved to be effective compared to the others and meets the objectives set in this work, and appears to be an accessible and least expensive means of increasing maize yield in the MPOYI group, where there is significant soil colonization by weeds in the Ngandajika territory.

Thus, we confirm our alternative hypothesis, which states that: Conversely, we say that the different frequencies of weeding or manual weeding tested in maize cultivation would not have the same field performance in the MPOYI group because everything would depend on the different parameters, namely the mode of action of each weeding frequency; the level of implementation of cultural practices; and the adaptability of each weeding frequency to the microclimate of the MPOYI group in the Ngandajika territory.

This performance demonstrated by the frequency of three manual weedings in the fight against weeds in maize crops in the MPOYI group in Ngandajika territory could be explained by the positive effects of repeated weeding, which consist of a considerable reduction in competition between the crop and weeds with regard to water, mineral elements and light. This better yield of dry maize grains shown by this frequency of three manual weedings could also be due to the local variation of some ecological factors, notably rainfall and edaphic characteristics, which proved relatively more favorable in the MPOYI group during the experiment. Thus, it is essential for farmers in the MPOYI group to adopt the frequency of manual weeding three times, particularly 15, 30 and 45 days after sowing in maize crops in order to effectively combat weeds and obtain considerable increases in the yield of dry maize grains.

It would also be desirable in the future to resume our trial on other cultivated varieties of maize, in other agro-ecological environments and in different growing seasons to maximize large-scale maize production in this rural area of the MPOYI group in Ngandajika territory. This attitude raises the concern to seek a better weed management strategy that combines efficiency, viability, sustainability and profitability.

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