Original Research Article

Screening of Phenoxyacetic Acid Derivatives In Rainfed Rice

ABSTRACT

In Côte d'Ivoire, the yield of rainfed rice (Oryza sativa) contributing to more than 80% of production is low. To address this constraint, seven phenoxyacetic acid derivatives were evaluated. The trial was conducted in Azaguié for two months under rainfed conditions and in a semi-controlled environment on vegetative material of three rice varieties (WAB638-1, C26 and NERICA 2). The design was a split-plot and observations were made on height, girth, vigor index and tillering. Results showed that the number of tillers/plant of WAB638-1 was improved to: 366.60 % by 2.4-DMPAA 10^{-5} M (WAB638-1), (171%) by 2.4-DMPPA 10^{-7} M (C26) and 150% by ACPP 10^{-5} M and ACMPP 10^{-5} M (NERICA 2). Circumference was increased: (80.37%) by ACMPP 10^{-7} M (WAB638-1), (83.17%) by ACMPP 10^{-9} M (C26) and (38.83%) by ACMPP 10^{-5} M (NERICA 2). The height of WAB638-1 was greater with: 6.76% by 2.4-DMPAA 10^{-5} M and ACPP 10^{-5} M (6.36%) followed by ACPP 10^{-7} M (4.92%) and reduced by the derivatives 2.5-DMPAA and 2.4-DCPAA. All derivatives inhibited C26 size except ACMPPA 10^{-7} M which was identical to the control. With NERICA 2, ACPA 10^{-7} M had the greatest size (22.39%). The vigor index was greater with 2.4-DMPP 10^{-7} M (9.52%) and ACMPP 10^{-7} M (9.52%) at WAB638-1, ACMPP 10^{-7} M (10.40%), ACPP 10-7 M (7.5%) and 2.4-DMPPA 10^{-7} M (7.5%) for C26 and ACPP 10^{-5} M (15.15%) and ACMPP 10^{-7} and 10^{-9} M (12.12%) regarding NERICA 2. Based on these results, the 2.4-DMPP, ACMPP and ACPP derivatives were retained at 10-5 M and 10^{-7} M concentrations.

Keywords: rice, Oryza sativa L, growth regulators, auxin derivatives, Côte d'Ivoire

1. INTRODUCTION

As the world's population increases, agricultural production should increase proportionally in order to feed it. This increase could be achieved by increasing the area of arable land or by improving yields. Nowadays, with the deforestation linked to rapid urbanization, only a tiny region of the planet can significantly increase the agricultural area [1]. Therefore, improving the yield and productivity of crops, especially rice, on arable land is becoming a necessity. In sub-Saharan Africa, particularly in Côte d'Ivoire, rice is consumed in most households at least once a day and is replacing traditional staple foods [2]. As the third most important food crop after yam and cassava, rice contributes to about 17% of total agricultural employability, coming in third place after cocoa and market gardening; it contributes to 9.9% of Ivorian GDP [3]. The improvement of its grain yield is traditionally done by fertilizers including organic matter (manure, droppings, liquid manure...), green manures (leguminous plants fixing atmospheric nitrogen) and chemical NPK fertilizers implemented by agricultural research [4]. Despite these inputs, the average yield (1.24 t/ha) of rainfed rice cultivation in rural areas remains low [5]. This suggests the adoption of new technologies that are environmentally friendly, cost-effective and easy to use, to enable rice varieties to express their grain yield potential. This could be achieved through genetic improvement, innovative cropping systems, grafting, growth promotion by microorganisms, and plant growth regulators [6]. Since their discovery, natural and artificial plant growth regulators are increasingly used in horticulture and agriculture to modify crop plants [7]. Indeed, they are involved in various metabolic processes of plants. Among these hormones, auxins constitute a class controlling plant growth and development processes [8]. The effect of improving fruit formation by exogenous supply of auxins has been demonstrated in tomato [9]. One of the auxin derivatives notably naphthalene acetic acid optimized the potential grain yield of rice [10, 11]. The use of some phenoxyacetic acid derivatives in banana improved the fruit yield of this crop [12]. In order to fill the rice production gap in Côte d'Ivoire, it seemed appropriate to evaluate the effect of other phenoxyacetic acid derivatives on the yield of three rice varieties.

2. MATERIAL AND METHODS

2.1 Experimental site

The trial was conducted at Abbé, a crossroads with geographic coordinates of 5°37'39'' North and 4°01'31'' West. Abbé is part of the municipality of Azaguié which is in the south of Côte d'Ivoire, 40 km north of Abidjan between 5°38' and 5°00' North and 4°05' and 4°00' West [13]. The Attean type climate is characterized by two rainy seasons (average rainfall of 1400 mm) and two dry seasons. The long rainy season extends from May to mid-July and the short one from mid-September to October. The long dry season begins in November and ends in April; the short dry season covers the period from mid-July to mid-September [14]. Rainfall is abundant and the average annual temperature is 28°C [1]. The vegetation is fallow and the soil is clayey-sandy with a fairly consistent texture. The soil has an acid pH (5.5) with a low organic matter content (1.44%). Its physico-chemical composition varies according to the horizon explored. Thus, the C/N ratio is 52.5 for the 0-20 cm horizon and 67.6 for 20-40 cm. The total phosphorus content varies from 214.75 to 229.08 mg.kg-1, the assimilable phosphorus content is estimated at 53 ppm, carbon varies from 5.78 to 3.38 g.kg-1 and nitrogen from 0.11 to 0.05 g.kg-1 [1].

2.2 Material

The plant material consisted of three rice varieties developed by AfricaRice

The variety WAB638-1, selected from an aromatic local population, can be grown under both rainfed and irrigated conditions. It has a long cycle of 135 days and a vegetative phase of 60 days. At maturity, this variety has an average height of 135 cm, a yield between 4.5 and 6 t/ha with a 1000 grain mass of 24.1 g [15].

NERICA is the result of an interspecific cross between Oryza sativa (L.), a high-yielding Asian rice variety, and Oryza glaberrima (Steud), a rice variety originating from Africa that is more resistant to biotic stresses [16]. NERICA 2 is a cross between WAB56-104/CG 14//2 and WAB56-104. It is grown under rainfed conditions with an average cycle of 95 to 100 days. The vegetative phase lasts from 30 to 45 days. Its yield is 4 t/ha with a mass of 1000 grains of 26 g, an average height at maturity of 105 cm.

The variety C26 of pure lineage, is tolerant to the drought. It is cultivated under irrigation conditions and in the lowlands. It is a variety with an average cycle of 102 days. It has an average height at maturity of 102 cm, a yield of 4.5 to 6 t/ha and a 1000 grain weight of 22.25 g [17].

WAB638-1 was chosen because it is highly valued by the population for its taste; NERICA 2 and C26 for their earliness.

The auxin compounds derived from phenoxyacetic acid used, were synthesized by the Organic Chemistry Laboratory according to the method of Pokorny cited by (Zimdahl, 2010). They include four groups:

- ✓ phenoxyacetic acid (PCAA);
- ✓ chlorinated derivative: 2.4-dichlorophenoxyacetic acid (2.4-DCPAA);
- ✓ methyl derivatives:
  - 2.5-dimethylphenoxyacetic acid (2.5-DMPAA);
  - methylphenoxyacetic acid (ACMA);
- ✓ derivatives with propanoic chains
  - simple propanoic: phenoxypropanoic acid (PPPA);
  - propenoic and methyl :
    - 2.4-dimethylphenoxypropanoic acid (2.4-DMPPA);
    - methylphenoxypropanoic acid (ACMPP).

2.3 Methods

The trial was conducted in a semi-controlled environment. The experimental design used was a randomized split-plot with 3 replicates with three factors: derivatives (ACPA, 2.4-DCPAA, 2.5-DMPAA, ACMA, ACPP, ACPP and ACMPP), concentrations (10^{-5} M, 10^{-7} M and 10^{-9} M) and varieties (WAB638-1, C26 and NERICA 2). The experimental units consisted of elementary lots of 135 plants in bags of 28 x 20 cm filled with soil from the 0-20 cm sterilized horizon. They were spaced 0.5 m apart and subdivided into three sublots of 45 plants, each representing a hormone at one of the concentrations. These subplots were also made up of three batches of 15 plants spaced 0.5 m apart representing a hormone with a concentration associated with each variety and constituted the treatments (Figure 1). The total area of the experiment was 177.30 m2 or 27.30 m x 6.5 m. Two weedings were done 21 and 40 days after sowing (jas); the plants were watered every 2 days according to the needs of the crop. The trial was conducted over a period of 60 d. Solutions of 10^{-5} M, 10^{-7} M and 10^{-9} M concentrations of the derivatives, obtained by diluting the stock solutions to 10-3 M, were applied to the rice plants in the early morning. Three foliar applications were made from day 15 to day 25 with a spacing of 5 days

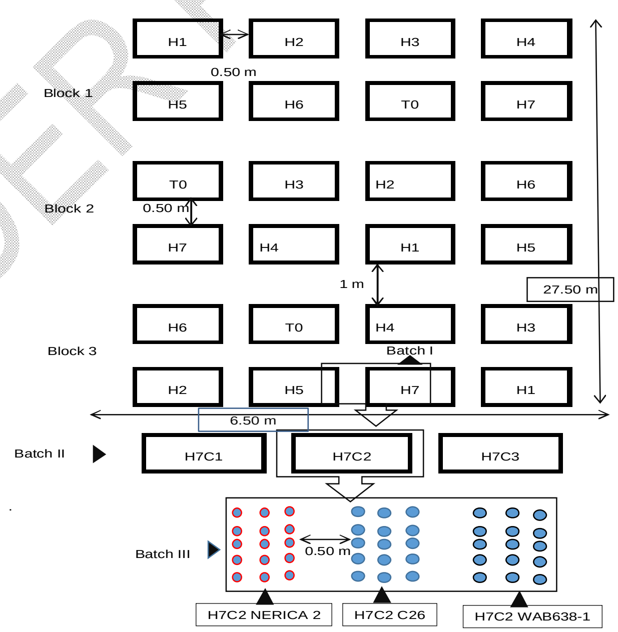

Figure 1: Experimental setup

H1 : 2.5-DMPAA, H2 : 2.4-DCPAA, H3 : 2.4-DMPPA, H4 : ACPA, H5 : ACPP, H6 : ACMA, H7 : ACMPP
V1. WAB638-1, V2. C26, V3. NERICA 2

2.4 Parameters studied

In this study, growth was assessed by height and girth dimensions; development by plant tillering. Measurements were taken for a given treatment, on a sample of 45 plants representing the number of plants in the three blocks for the treatment. Measurements started on day 30 and were taken every 15 days.

2.5 Height

Height measured with a tape measure from the crown to the tip of the leaves of the main plants was expressed in centimeters (cm).

2.6 Circumference

The circumference of the clumps of rice plants was measured at the collar of the rice plants using a using a tape measure and expressed in cm.

2.7 Number of tillers

The number of tillers was counted per plant and the average was expressed as tillers/plant.

2.8 Vigor index

The vegetative vigor index (IV) calculated according to the formula of [17] which was modified and adapted to our trial using the circumference C π =D.

$IV = \log (C^2 \times H/4\pi.)$

C: circumference (cm), H: height (cm) and $\pi = 3.14$

2.9 Rate of increase

The rate of increase (ROI) indicating the activity of the derivatives on the parameters: height, circumference, vigor index or tillering, was calculated according to the formula in [18].

$TA (\%) = [(Tn - T0) / T0] \times 100$

T0 : height, girth or tillering of control plants

Tn : height, circumference or tillering of treated plants.

2.10 Statistical analysis

The collected data were subjected to an analysis of variance (ANOVA) using STATISTICA 7.1 software. The ANOVA was used to compare the effect of phenoxyacetic acid derivatives on the parameters studied. In case of a significant effect of the treatment, the Newman-Keuls test of comparison of means was applied to classify them into homogeneous groups at the 5% threshold. A principal component analysis (PCA) performed with the LXSTAT software was used to characterize the best derivatives.

3. Results

3.1 Height

Plant height and growth rates relative to the controls of the three varieties presented in Table 1, shows a difference with the treatments regardless of the variety ($P< .05$). The height of the control plants was 97.58 cm (WAB638-1), 80.33 cm (C26) and 84.40 cm (NERIA 2). The height of the treated plants varied from 94.92 to 103.75 cm (WAB638-1), 57.50 to 83.58 cm (C26) and 84.40 to 103.30 cm (NERICA 2).

The highest height of WAB638-1 was obtained with the treatment 2.4-DMPAA $10^{-5\ M}$ (104.17 cm) with an increase rate of (6.76 %) and ACPP 10^{-5} M (103.75 cm) for an increase rate of 6.36 % followed by the treatment ACPP 10^{-7} M which recorded a height of 102.42 cm (4.92 %). The lowest height was given by the 2.4-DCPAA 10^{-9} M treatment (94.9 cm). The other treatments were intermediate.

For the C26 variety, the best sizes were recorded with the ACMPP 10^{-7} M treatments (83.58 cm) and the control (80.33 cm).

Concerning the variety NERICA 2, all the derivatives had a positive effect on this variable. However, the highest height was observed with the ACPA treatment at 10^{-7} M. It increased this parameter by 22.39% (103.39 cm) and the control plants with the lowest height. The derivatives 2.5-DMPAA and 2.4-DCPAA reduced, whatever the concentration, the height of the variety WAB638-1 and in C26. This variable was also reduced by all derivatives except 10^{-7} M ACMPP. At concentrations of 10^{-5} M and 10^{-9} M, the compounds (2.4-DMPPA and ACPP) stimulated the apical meristems at the leaf apices and activated the intercalary meristems of the internodes via gibberellins. This led to cell elongation. Our results corroborate those of [19] who obtained an improvement in the height of chickpea by spraying indole-3-butyric acid; as well as those of [20] who, treating rice varieties with naphthalene acetic acid obtained higher heights compared to the control.

3.2 Circumference

The circumference of the plants varied from 10.50 to 19.30 cm (WAB638-1); 9.70 to 18.50 cm (C26); 6 to 12 cm (NERICA 2) and 10.70 to 8.90 cm (controls) with a highly significant difference (P<.05) (Table 2). with WAB638-1, the lowest circumference, was observed with 2.5-DMPAA 10^{-5} M. This value which was smaller was not statistically different from the control (10.70 cm). ACMPP 10^{-7} M, allowed the plants to have the greatest radial growth (19.30 cm or 80.37 %). It was followed by 2.4-DMPPA 10^{-7} M (18.10 cm or 69.16 %), ACMPP 10^{-5} M (16.60 or 55.40 %) and ACMPP 10^{-7} M (16.20 cm and 51.40 %). ACMPP 10^{-5} M and ACMPP 10^{-7} M belonging to the same group were statistically different from 2.4-DMPPA 10^{-7} M.For variety C26, ACPP 10^{-5} M whose mean

Table 1. Effect of auxin derivatives on height

Phenoxyacetic acid derivatives	Concentrations (M)	WAB638-1		C26		NERICA2	
		Height (cm)	AR (%)	Height (cm)	AR (%)	Height (cm)	AR (%)
Witnesses	C0: 0	97.58 de	-	80.33 a	-	84.40 b	-
2,5-DMPAA (H3)	C1:10^{-5}	95.08e	-2.56	64.50 gh	-19.68	98.00 ab	16..
	C2 :10^{-7}	96.33 de	-1.33	67.08fg	-16.44	95.20 ab	12.80
	C3 :10^{-9}	96.83 de	-4.92	57.50 i	-28.39	94.10 ab	11.49
2,4-DCPAA (H2)	C1:10^{-5}	96.25 de	-1.33	61.58 hi	-23.29	91.00 ab	7.82
	C2 :10^{-7}	96.75de	-0.82	58.42 hi	-27.27	99.00 ab	17.30
	C3 :10^{-9}	94.92 e	-2.77	62.42 hi	-22.29	99.00 ab	17.30
2,4-DMPPA (H6)	C1:10^{-5}	104.17 a	6.76	72.67 b	-9.46	86.30 ab	2.25
	C2 :10^{-7}	98.33 cd	0.72	64.33 gh	-19.93	97.30 ab	15.28
	C3 :10^{-9}	97.58 de	-0.41	65.25 gh	-18.80	100.90ab	19.55
ACPA (H1)	C1:10^{-5}	99.92 cd	2.36	66.08 fg	-17.68	92.00 ab	9.00
	C2 :10^{-7}	102.00 bc	4.51	69.08 ef	-13.95	100.10 ab	18.60
	C3 :10^{-9}	101.08cd	3.59	71.98 bc	-10.46	90.10 ab	6.75
ACPP (H5)	C1:10^{-5}	103.75 a	6.35	70,25cd	-12.58	93.20 ab	10.43
	C2 :10^{-7}	102.17 bc	4.71	63.83 hi	-20.55	92.60 ab	9.72
	C3 :10^{-9}	96.42e	-2.25	64.08 hi	-20.17	103.30 a	22.39
ACMA (H4)	C1:10^{-5}	98.08cd	0.51	63.31 hi	-21.30	93.30ab	10.55
	C2 :10^{-7}	99.75 cd	2.25	70.71 de	-12.70	88.60 ab	4.98
	C3 :10^{-9}	98.92 cd	1.33	66.70 fg	-16.94	88.10 ab	4.38
ACMPP (H7)	C1:10^{-5}	99.25cd	1.74	63.17 hi	-21.30	95.50 ab	13.15
	C2 :10^{-7}	102.42 ab	4.92	60.58 hi	-24.53	97.07 ab	15.01
	C3 :10^{-9}	96.92 de	-0.72	83.58 a	4.11	94.40 ab	11.85
Newman-Keuls P < .05		0.00		0.00		0.00	

Values with different letters in the same column differ at the 5% level of the Newman-Keuls test.

AR: rate of increase relative to the control

was 16.70 cm or 65.35% was preceded by ACMPP 10^{-9} M (18.5 cm or 83.17%). ACMA 10^{-7} M had the lowest value (9.70 cm).

Regarding NERICA 2, ACMA, 2.4-DCPAA and 2.5-DMPAA derivatives at all concentrations and ACPA 10^{-5} M, showed regressive effects. ACMPP, ACPP and 2.4-DMPPA derivatives, had a positive effect. Among them, those improving this parameter the most were ACMPP 10^{-5} M (12 cm or 34.83%) followed by ACMPP 10^{-5} M and ACPP 10^{-7} M with an average of 11.40 cm, increasing by a rate of 28.09%. The treatments that induced optimal development of the circumference would have caused proliferation of the generative libero-ligneous zone at these concentrations leading to differentiation of the xylem and phloem layers thus causing thickening at the neck of the clumps [21, 22, 23]. Similar results were obtained by [24] by increasing the girth of okra stems with auxin and also by [25] by improving the diameter of xylem vessels of Populus using the growth regulator meme. The inhibitory effect of 2.5-DMPAA and 2.4-DCPAA on the height of WAB638-1 and circumference of NERICA 2 as well as ACMA and ACPA 10^{-5} M of the circumference of the latter variety would be related to a specific chemical toxicity. These results are in agreement with those of Baker and Weitzstein (2004) [26, 27] and Staswick et al. (2005) who reported that the toxicity was related to.

3.3 Vigor index

The average heights and neck girths measured for each treatment and variety were used to calculate vigor indices (Table 3). They showed significant differences between treatments ($P<.05$). The results reveal that the plants of the variety WAB638-1 treated with the derivatives ACMPP and 2.4-DMPP at 10^{-7} M, gave the highest vigor indices. For these two treatments, the average value of the vigor index was 4.60 with the respective growth rates of 9.52% followed by the 10^{-5} M ACMPP derivative (4.5 or 7.14%). The 2.5-DMPAA 10^{-7} M with 4.10 obtained the lowest value statistically identical to the control.

At C26, plants treated with ACMPP 10^{-9} M (4.40 or 10%) and 2.4-DMPPA 10^{-5} M (4.30 or 7%) had the highest vigor indices with identical influence. Their effect was followed by those of 10^{-7} M ACPA and 2.4-DMPPA 10^{-7} M and 10^{-9} M concentrations with an average of 4.20 (5%). The treatments 2.5-DMPAA 10^{-9} M, ACPP 10^{-5} M and ACMA 10^{-5} M, gave the lowest values with an average of 3.9.

For NERICA 2, plants sprayed with ACMA 10^{-5} M and 10^{-7} M had a lower vigor index than the control (2.90 and 3.10 or -12.12 and -6.06 %). In contrast, plants sprayed with ACMPP 10^{-5} M (3.80 or 15.15 %) and 10^{-7} M (3.70 or 12.20%) and CAPP 10^{-5} M (3.80 or 15.15%) recorded the highest vigor indices with corresponding growth rates. The positive influence of on the vigor index, reflects the good accumulation of organic matter in these varieties under these treatments [1]. Indeed, they would have increased the accumulation of some microelements such as nitrogen, magnesium and iron that are included in the synthesis of chlorophyll, which increased the photosynthetic efficiency and the manufacture of organic matter. Our results are close to those of [28]. The latter obtained an improvement in the vigor index of stigmas of a hybrid rice treated with gibberellin.

3.4 Number of stubs

The results for the activity of derivatives on tillers, reported in Table 4 show that the average numbers of tillers were significant for all varieties. WAB638-1 plants had the highest numbers with 2.4-DMPAA 10^{-5} M (14 14 Heels/foot or 366.6%) followed by ACPP 10^{-5} M (12 Heels/foot or 300%) and ACMPP 10^{-5} M and 10^{-7} M (11 Heels/foot or 266.6%). These treatments were not statistically different.

The number of tillers produced by plants treated with the derivatives 2.5-DMPAA at the three concentrations, 2.4-DCPAA 10^{-7} M and 10^{-9} M, ACPP 10^{-9} M, ACMA 10^{-5} and 10^{-7} M varied from 3 to 4 Heels/foot without difference with the control which also produced 3 Heels/foot With the variety C6, all the derivatives favored tillering whatever the concentration compared to the control which produced 7 Heels/foot. However, the most favorable was 2.4-DMPPA 10^{-7} M (19 Heels/foot equivalent to 171.4% compared to the control). The ACPP 10^{-7} M derivative that follows it

Table 2. Effect of auxin derivatives on girth

Phenoxyacetic acid derivatives	Concentrations (M)	WAB638-1		C26		NERICA2	
		Circumference (cm)	AR (%)	Circumference (cm)	AR (%)	Circumference (cm)	AR (%)
Witnesses	**C0: 0**	10.70 fg	-	10.10 gh	-	8.90 cd	-
2,5-DMPAA (H3)	**C1:10^{-5}**	10.50 fg	-1.87	11.10 gh	9.90	6.80 ef	-23.60
	C2 :10^{-7}	12.20 f	14.02	1150 gh	13.86	8.00 ef	-10.11
	C3 :10^{-9}	11.70 fg	9.35	10.40 gh	2.97	6.00 ef	-32.58
2,4-DCPAA (H2)	**C1:10^{-5}**	11.80 fg	10.28	11.60 gh	14.85	600 ef	-32.58
	C2 :10^{-7}	11.70 fg	9.35	11.70 gh	15.84	6.00 ef	-32.58
	C3 :10^{-9}	11.90 fg	11.21	12.20 fg	20.79	6.90 ef	-22.47
2,4-DMPPA (H6)	**C1:10^{-5}**	15.20 cd	42.06	15.60 bc	54.46	10.60 bc	19.10
	C2 :10^{-7}	18.10 b	69.16	14.20 cd	40.59	10.30 bc	15.73
	C3 :10^{-9}	13.60 e	27.10	14.00 cd	38.61	8.70 cd	-2.24
ACPA (H1)	**C1:10^{-5}**	15.40 cd	43.93	12.20 fg	20.79	7.20 ef	-19.10
	C2 :10^{-7}	15.00 cd	40.19	13.30 de	31.68	9.40 cd	5.62
	C3 :10^{-9}	14.70 de	37.38	15.20 bc	50.50	8.70 cd	-2.25
ACPP (H5)	**C1:10^{-5}**	11.70 fg	9.35	13.00 ef	28.71	11.40 ab	28.09
	C2 :10^{-7}	16.20 cd	51.40	16.70 b	65.35	10.40 bc	16.85
	C3 :10^{-9}	10.50 fg	-1.87	10.20 gh	0.99	10.40 bc	16.85
ACMA (H4)	**C1:10^{-5}**	10.20 g	-4.67	11.60 gh	14.85	5.40 f	-39.33
	C2 :10^{-7}	11.30 fg	5.61	9.70 h	-3.96	5.70 ef	-35.96
	C3 :10^{-9}	11.50 fg	7.48	10.90 gh	7.92	7.10 ef	-20.22
ACMPP (H7)	**C1:10^{-5}**	16.60 c	55.14	13.20 ef	30.69	12.00 a	34.83
	C2 :10^{-7}	19.30 a	80.37	12.10 gh	19.80	11.40 ab	28.09
	C3 :10^{-9}	15/70 cd	46.73	18.50 a	83,17	10.10 cd	13.48
Newman-Keuls P < .05		0.00		0.01		0.00	

Values with different letters in the same column differ at the 5% level of the Newman-Keuls test

AR: rate of increase relative to controls

increased tillering (17 Heels/foot or 142%).

At the level of NERICA 2 2.4-DCPAA 10^{-5} M exerted an inhibitory effect on the production of tillers as well as ACMA 10^{-7} M. The 2.5-DMPAA 10^{-7} M and 2.5-DMPAA 10^{-9} M treatments on the one hand and ACPA 10^{-7} M and ACPA 10^{-9} M on the other hand with 5 tillers/plant were close to the control. ACPP 10^{-5} M producing 15 tillers/plant and stimulating tillering by 150% was more effective for this variety. Under 10^{-7} M and 10^{-9} M, ACMPP on the one hand and ACPP derivative on the other hand and 2,4-DMPPA 10^{-5} M and 2,4-DMPPA 10^{-7} M treatments which produced 13; 11 and 12 Heels/foot respectively were statistically identical. Their effect was subjacent. Tiller production had a gain of 116.7; 80.3 and 100%. The improvement in tillering obtained would reflect the stimulating effect of these analogues on the internal cytokines of the varieties, which favoured the differentiation of the buds, their bud break, and their emergence. Our results are in agreement with those of [29, 20, 30]. Indeed, the former obtained an increase in the number of tillers by foliar spraying of naphthalene acetic acid on rice. The latter showed that pretreatment of rice grains with indole butyric acid increased the number of tillers.

3.5 Relationships between derivatives, concentrations and parameters studied

Principal component analysis (PCA) was used to characterize the treatments in order to select the most efficient ones on plant growth and development. The projection of variables and individuals in the factorial plant defined two axes, F1 and F2 for each variety.

Table 3. Influence of auxin derivatives on vigor index

Phenoxyacetic acid derivatives	Concentrations (M)	WAB638-1		C26		NERICA2	
		Strength index	AR (%)	Strength index	AR (%)	Strength index	AR (%)
Witnesses	**C0: 0**	4.20 de	-	4.0fg	-	3.30 cd	-
2,5-DMPAA (H3)	**C1:10^{-5}**	4.10 e	-2.38	4.00 fg	0.00	3.40 cd	3.03
	C2 :10^{-7}	4.20 d	0.00	4.10 fg	2.50	3.20 cd	-3.03
	C3 :10^{-9}	4.20 de	0.00	3.90 g	-2.50	3.20 cd	-3.03
2,4-DCPAA (H2)	**C1:10^{-5}**	4.20 d	0.00	4.00 fg	0.00	3,20 cd	-3.03
	C2 :10^{-7}	4.20 de	0.00	4.00fg	0.00	3.20 cd	-3.03
	C3 :10^{-9}	4.20 de	0.00	4.10 gf	2.50	3.40 cd	3.03
2,4-DMPPA (H6)	**C1:10^{-5}**	4.50 bc	7.14	4.30 a	7.50	3.60 ab	9.09
	C2 :10^{-7}	4.60 a	9.52	4.20 c	5.00	3.60 bc	9.09
	C3 :10^{-9}	4.40 c	4.76	4.20 c	5.00	3.20 cd	-3.03
ACPA (H1)	**C1:10^{-5}**	4.40 bc	4.76	4.10 ef	2.50	3.40 ad	3.03
	C2 :10^{-7}	4.30 c	2.38	4.20 c	5.00	3.60 ab	9.09
	C3 :10^{-9}	4.40 c	4.76	4.30 ab	7.50	3.40 ad	3.03
ACPP (H5)	**C1:10^{-5}**	4.20 de	0.00	4.10 cd	2.50	3.80 a	15.15
	C2 :10^{-7}	4.50 b	7.14	4.30 a	7.50	3.60 ab	9.09
	C3 :10^{-9}	4.10 de	-2.38	3.90 fg	-2.50	3.60 ab	9.09
ACMA (H4)	**C1:10^{-5}**	4.10 de	-2.38	4.00 fg	0.00	2.90 d	-12.12
	C2 :10^{-7}	4.20 de	0.00	3.90 fg	-2.50	3.10 cd	-6.06
	C3 :10^{-9}	4.20 de	0.00	4.00 fg	0.00	3.30 cd	0.00
ACMPP (H7)	**C1:10^{-5}**	4.50 b	7.14	4.10 de	2.50	3.80 a	15.15
	C2 :10^{-7}	4.60 a	9.52	4.10 de	2.50	3.70 a	12.12
	C3 :10^{-9}	4.40 bc	4.76	4.40 a	10.00	3.70 a	12.12
Newman-Keuls P < .05		0.00		0.00		0.00	

Values with different letters in the same column differ at the 5% level of the Newman-Keuls test

AR: rate of increase relative to controls

These two axes express 96.93% (WAB638-1), 86.76% (C26) and 92.43% (NERICA 2) of the total variability (WAB638-1: figure 1, C26: figure 2, NERICA 2: figure 3). Individuals favoring growth and development parameters are those far from the origin of the axis, close to each other and clustered around the variables. These individuals were grouped into three groups for each variety.

In WAB638-1 all variables are positively correlated with the F1 axis. The 1st group (GI) is constituted by the treatments H3C1 (2.5-DMPAA 10^{-5} M), H3C3 (2.5-DMPAA 10^{-9} M), H2C3

(2.4-DCPAA 10^{-9} M) , H2C2 (2.4-DCPAA 10^{-7} M), H2C1(2.4-DCPAA 10^{-5} M), H3C2 (2. 5-DMPAA 10^{-7} M), H4C1 (ACMA 10^{-5} M), H4C2 (ACMA 10^{-7} M), H4C3 (ACMA 10^{-9} M), H5C3 (ACPP 10^{-9} M), and H6C3 (2.4-DMPA (10^{-9} M) had an effect close to the control. The 2nd group (GII) improving height included the H5C1 (CAPP 10^{-5} M) treatments. Those in the 3rd group (GIII) formed by treatments H1C2 (ACPA (10^{-7} M), H1C3 (ACPA 10^{-9} M), H1C1 (ACPA 10^{-5} M), H7C3 (ACMPP 10^{-9} M), H7C1 (ACMPP 10^{-5} M), H7C2 (ACMPP 10^{-7} M), H6C1 (2. 4-DMPPA 10^{-5} M), H5C2 (ACPP 10^{-7} M), and H6C2 (2.4-DMPA (10^{-7} M) had greater activity on tillering, girth, and vigor index.

In the C26 variety, apart from height which is positively correlated to the F2 axis, all other variables are positively correlated with the F1 axis. Group I (GI) includes the H7C2 treatment (ACMPP 10^{-7} M) which had the same effect as the TC0 control. Group II (GII) consists of treatments H3C2 (2.5-DMPAA 10^{-7} M), H4C2 (ACMA 10^{-7} M), H4C3 (ACMA 10^{-9} M), H1C1 (ACPA 10^{-5} M), H5C3 (ACPP 10^{-9} M), H3C1 (2. 5-DMPAA 10^{-5} M), H4C1 (ACMA 10^{-5} M), H2C3 (2.4-DCPAA 10^{-9} M), H3C3

Table 4. Effect of auxin derivatives on the amount of tillers

Phenoxyacetic acid derivatives	Concentrations (M)	WAB638-1		C26		NERICA2	
		Heels/foot	AR (%)	Heels/foot	AR (%)	Heels/foot	AR (%)
Witnesses	**C0: 0**	3.00 e	-	7.00 i	-	6.00 bc	-
2,5-DMPAA (H3)	**C1:10^{-5}**	3.00 e	0.00	10.00 gh	42.70	6.00 bc	0.00
	C2 :10^{-7}	3.00 e	0.00	9.00 gh	28.60	5.00 ac	-16.70
	C3 :10^{-9}	3.00 e	0.00	10.00 gh	42.90	5.00 bc	-16.70
2,4-DCPAA (H2)	**C1:10^{-5}**	6.00 d	100.00	13.00 de	85.70	2.00 c	-66.70
	C2 :10^{-7}	3.00 e	0.00	11.00 fg	57.10	6.00 bc	0.00
	C3 :10^{-9}	4.00 e	33.30	11.00 f	57.10	6.00 bc	0.00
2,4-DMPPA (H6)	**C1:10^{-5}**	14.00 a	366.60	14.00 c	100,0	12.0 ab	100.00
	C2 :10^{-7}	9.00 c	200.00	19.00 a	171.40	12.00 ab	100.00
	C3 :10^{-9}	8.00 c	166.60	12.00 ef	71.40	10.00 b	66.70
ACPA (H1)	**C1:10^{-5}**	9.00 c	200.00	10.00 gh	42.90	5.00 bc	-16.70
	C2 :10^{-7}	8.00 c	166.60	10.00 gh	42.90	6.00 bc	0.00
	C3 :10^{-9}	10.00 c	233.30	14.00 cd	100.00	5.00 bc	-16.70
ACPP (H5)	**C1:10^{-5}**	8.00 c	166.60	15.00 c	114.30	15.00 a	150.00
	C2 :10^{-7}	12.00 b	300.00	17.00 b	142.90	11.00 ab	83.3
	C3 :10^{-9}	4.00 e	33.30	11.00 fg	57.10	11.00 ab	83.30
ACMA (H4)	**C1:10^{-5}**	4.00 e	33.30	10.00 gh	42.90	6.00 bc	0.00
	C2 :10^{-7}	4.00 e	33.3	10.00 gh	42.90	5.00 bc	-16.66
	C3 :10^{-9}	6.00 d	100.0	11.00 gh	57.10	6.00 bc	0.00
ACMPP (H7)	**C1:10^{-5}**	11.00 b	266.6	13.00 d	85.70	15.00 a	150.00
	C2 :10^{-7}	11.00 b	266.60	13.00 d	85.70	13.00 ab	116.70
	C3 :10^{-9}	9.00 c	200.00	11.00 f	57.10	13.00 ab	116.70
Newman-Keuls P < .05		0.00		0.00		0.00	

Values with different letters in the same column differ at the 5% level of the Newman-Keuls test

AR: rate of increase relative to controls

(2.5-DMPAA 10^{-9} M), H2C1 (2.4-DCPAA 10^{-5} M), and H2C2 (2.4-DCPAA 10^{-7} M) did not have any effect on the different parameters. Group III (GIII) includes treatments H6C1 (2.4-DMPA 10^{-5} M), H1C3 (ACPA 10^{-9} M), H5C1 (ACPP 10^{-5} M), H1C2 (ACPA 10^{-7} M), H6C3 (2.4-DMPA 10^{-9} M),

H7C1 (ACMPP 10^{-5} M), H6C2 (2.4-DMPA 10^{-7} M), H5C2 (ACPP 10^{-7} M) and H7C3 (ACMPP 10^{-9} M). These treatments promoted vigor, girth and tillering indices.

As for the variety NERICA 2, the F1 axis is correlated to the number of tillers/plant and circumference and F2 to the vigor index and height. Group I (GI) treatments composed of H3C2 (2.5-DMPAA 10^{-7} M), H6C3 (2.4-DMPAA 10^{-9} M). H3C3 (2.5-DMPAA 10^{-9} M), H4C1 (ACMA 10^{-5} M), H4C2 (ACMA 10^{-7} M) had an effect close to the control. The 2nd group (GII) promoting height consisted of treatments H1C1 (ACPA 10-5 M), H1C3 (ACPA 10-9 M), H3C1 (2.5-DMPAA 10^{-5} M), H2C3 (2.4-DCPAA 10^{-9} M), H2C1 (2.4-DCPAA 10^{-5} M), H2C2 (2. 4-DCPAA 10^{-7} M), H4C3 (ACMA 10^{-9} M), The 3rd group (GIII) grouping treatments H7C3 (ACMPP 10^{-9} M), H7C1 (ACMPP 10^{-5} M), H7C2 (ACMPP 10^{-7} M), H5C3 (ACPP 10^{-9} M), H6C2 (2. 4-DMPA 10^{-7} M), H6C1 (2.4-DMPA 10^{-5} M), H5C2 (ACPP 10^{-7} M), H5C1 (ACPP 10-5 M) positively induced vigor index, tillering and girth. Treatment effects varied among varieties. At the individual variety level, Group I (GI) treatments had no effect. Those of group III (GIII) that positively induced both tillering, girth and vigor index. Among them, the influence of treatments from propanoic chain derivatives, H7C1, H7C2, H7C3 (ACMPPA), H6C1, H6C2, H6C3 (2.4-DMPPA) and H5C1, H5C2, H5C3 (ACPP) was more marked. These results show the diversity of actions that growth regulators have. According to [31], exogenous application of auxins induces different responses depending on their concentration and the effect of hormones depends on the cell receiving them. For the same group of substances, the responses can vary on the development of a plant and on the varieties of the same crop. These same results were observed in the work of [32]. Indeed, these authors having worked on phenoxyacetic acid and its derivatives in hydroponic culture of rejects observed that some treatments had the same effect as the control. The particular effect of ACMPP, 2.4-DMPPA and ACPP derivatives could be explained by the propanoic chain they possess. According to [32], the size of the side chain in the immediate vicinity of the nucleus of the molecule would contribute to its activity. This chain should be neither too long nor too short.

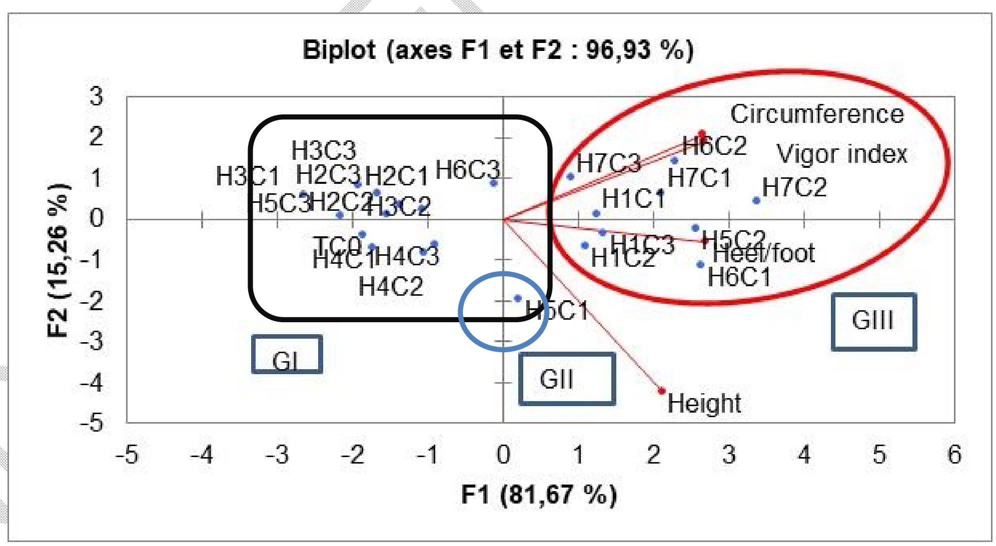

Figure 2. Representation of the WAB638-1 variety variables, derivatives and concentrations on the F1 and F2 axes using PCA

H1C1, H1C2 and H1C3 : ACPA (10^{-5} M, 10^{-7} M and 10^{-9} M), H2C, H2C2 and H2C3 : 2,4-DCPAA (10^{-5} M, 10^{-7} M and 10^{-9} M), H3C1, H3C2 and H3C3 : 2.5-DMPAA (10^{-5} M, 10^{-7} M and 10^{-9} M), H4C1, H4C2 and H4C3 : ACMA (10^{-5} M, 10^{-7} M and 10^{-9} M), H5C1, H5C2, and H5C3 : ACPP (10^{-5} M, 10^{-7} M and 10^{-9} M), H6C1, H6C2, H6C3 : 2.4-DMPPA (10^{-5} M, 10^{-7} M and 10^{-9} M and H7C1, H7C2 et H7C3 : ACMPP (10^{-5} M, 10^{-7} M and 10^{-9} M).

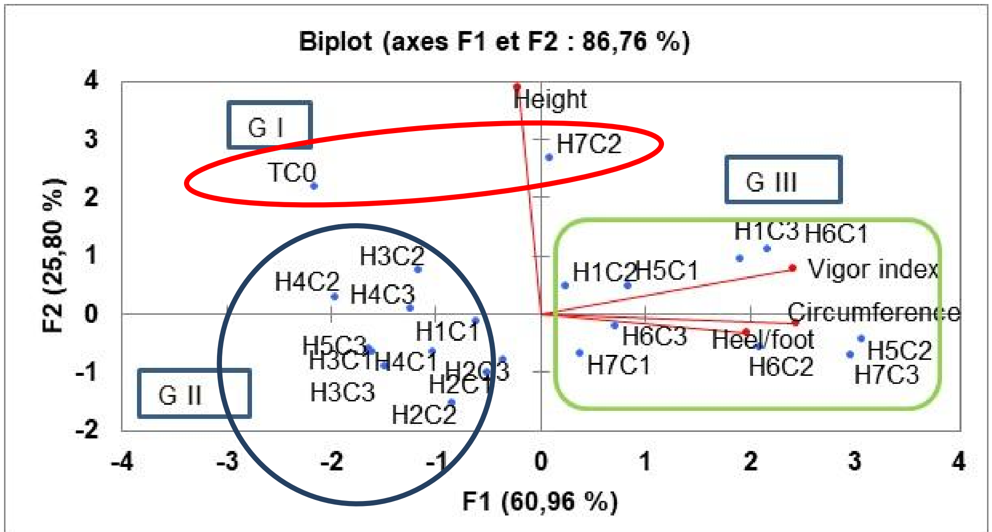

Figure 3. Representation of the C26 variety variables, derivatives and concentrations on the F1 and F2 axes using PCA

H1C1, H1C2 and H1C3 : ACPA (10^{-5} M, 10^{-7} M and 10^{-9} M), H2C, H2C2 and H2C3 : 2,4-DCPAA (10^{-5} M, 10^{-7} M and 10^{-9} M), H3C1, H3C2 and H3C3 : 2.5-DMPAA (10^{-5} M, 10^{-7} M and 10^{-9} M), H4C1, H4C2 and H4C3 : ACMA (10^{-5} M, 10^{-7} M and 10^{-9} M), H5C1, H5C2, and H5C3 : ACPP (10^{-5} M, 10^{-7} M and 10^{-9} M), H6C1, H6C2, H6C3 : 2.4-DMPPA (10^{-5} M, 10^{-7} M and 10^{-9} M and H7C1, H7C2 et H7C3 : ACMPP (10^{-5} M, 10^{-7} M and 10^{-9} M).

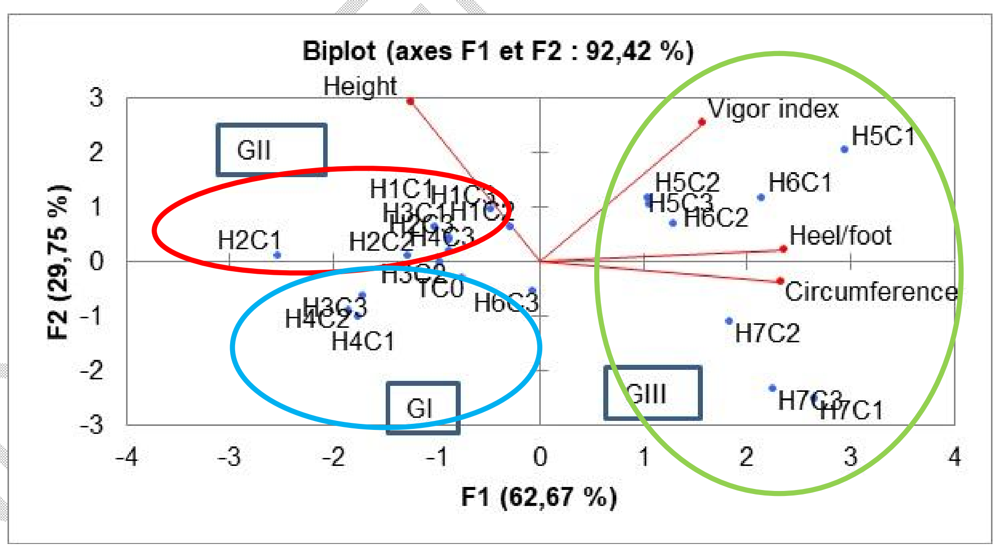

Figure 4. Representation of the C26 variety variables, derivatives and concentrations on the F1 and F2 axes using PCA

H1C1, H1C2 and H1C3 : ACPA (10^{-5} M, 10^{-7} M and 10^{-9} M), H2C, H2C2 and H2C3 : 2,4-DCPAA (10^{-5} M, 10^{-7} M and 10^{-9} M), H3C1, H3C2 and H3C3 : 2.5-DMPAA (10^{-5} M, 10^{-7} M and 10^{-9} M), H4C1, H4C2 and H4C3 : ACMA (10^{-5} M, 10^{-7} M and 10^{-9} M), H5C1, H5C2, and H5C3 : ACPP (10^{-5} M, 10^{-7} M and 10^{-9} M), H6C1, H6C2, H6C3 : 2.4-DMPPA (10^{-5} M, 10^{-7} M and 10^{-9} M and H7C1, H7C2 et H7C3 : ACMPP (10^{-5} M,

4. CONCLUSION

This study showed the real influence of some phenoxyacetic acid derivatives on the studied parameters. These effects varied according to the derivative, the concentration, the variety and the parameter. They were more important for the derivatives with propanoic chain. Those selected were ACPP, 2,4-DMPPA and ACMPP at concentrations 10-5 M and 10-7 M.

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