Original Research Article

Agronomic performance of *Hevea brasiliensis Muell. Arg.* clone IRCA 331 grown in Southwestern Côte d'Ivoire

Abstract

In order to test the agronomic performance of the newly developed clones, a Large-Scale Clone Trial (LSCT) comprising *Hevea brasiliensis* clones GT 1, IRCA 202, IRCA 331, IRCA 707, PB 280 and PB 310 was established in southwestern Côte d'Ivoire. They were planted in completely randomized blocks with six clone treatments and four replications of 112 trees per clone. The measured parameters included isodiametric growth of the trunk, rubber yield, trees stand, latex physiological parameters and sensitivity to tapping panel dryness (TPD). After ten years of downward tapping and four years of upward tapping, clone IRCA 331 showed significantly higher rubber productivity than all other clones. Its productivity gain, relative to the reference control GT 1, was 63% in downward tapping and 80% in upward tapping. Despite its high level of productivity, the annual rate of isodiametric growth of clone IRCA 331 tree trunks (2.56 cm/year) remained statistically equivalent to that of clone GT 1 (2.62 cm/year) at latex harvesting stage. In addition, the physiological profile of clone IRCA 331 was good and similar to that of the control. Clones IRCA 331, GT1 and PB 280 got the lowest sensitivity to TPD. However, only clones GT1 and IRCA 331 maintained a good stand of tappable trees throughout the experimental period. This experiment highlighted the agronomic performance of the clone IRCA331 and allowed to put it in class 1. Clone IRCA 331 can therefore be used as a clone of first choice to improve national productivity.

Keywords: *Hevea brasiliensis; rubber yield; vegetative growth; physiological profile; tapping panel dryness; Côte d'Ivoire.*

1. Introduction

Rubber tree cultivation is today a dynamic agricultural sector in full expansion in Côte d'Ivoire. According to the website www.ivoireabidjan, rubber tree cultivation ranks 3rd among export products with a total export income of 106 billion FCFA in 2005. In 2006, the sector achieved a turnover of nearly 200 billion CFA francs of which 33 billion by producers. The sector distributed 35 billion to farmers in the same year. From this point of view, rubber tree cultivation appears to be a support for the government's policy of fighting against poverty in rural areas. It contributes to the creation of national wealth by increasing the gross domestic product, and also to ecological and environmental balance [1,2,3]. This good momentum is due to the political will shown by the State since 1964 and the unity of the stakeholders in the rubber tree sector gathered within the Association of Natural Rubber Professionals of Côte d'Ivoire (APROMAC). The sector is accompanied by agronomic research that breeds high yielding clones, adapted to the agro-climatic conditions of the country. This has enabled Côte d'Ivoire to be Africa's leading producer of natural rubber, with a yield of 624 000 tons in 2018 over a planted area of 300 000 hectares [4]. The clonal selection scheme adopted by almost all rubber tree breeders has three phases, namely the Seedling Evaluation Trial (SET), the Small-Scale Clone Trial (SSCT) and the Large-Scale Clone Trial (LSCT) [5]. However, the selection criteria used are adapted to the difficulties that hinder the development of rubber tree cultivation in each country. Thus, in Côte d'Ivoire, selection is mainly focused on the yield per hectare. The latter is conditioned by clone vigor [6,7], its yield per tree and its resistance to stand trees reduction factors such as tapping panel dryness and wind damage [8,9,10,11] [12]. The physiological profile, through sucrose, inorganic phosphorus, thiol group and latex dry rubber content is taken into account as secondary criteria in order to assess the influence of the intensity of rubber biosynthesis metabolism. The physiological profile also helps to determine the ability of clones to bear tapping and hormonal stimulation related stress [12,13,14,15,16]. The clones received by Côte d'Ivoire in international exchanges with rubber tree research institutes are tested directly in LSCT. Thus, a LSCT was established and monitored in southwestern Côte d'Ivoire to compared to the control GT 1, two clones received from Malaysia (PB 310 and PB 280) and three clones created in Côte

d'Ivoire. After 14 years of latex harvesting including ten years of downward tapping and four years of upward tapping, the agronomic performance of clone IRCA 331 have been highlighted.

2. MATERIAL AND METHODS

2.1. Experimental site and plant material

The experiment was carried out on the research and experimental station of Go located in the southwest (5°40' North, 6°43'West) of Côte d'Ivoire. This region is characterized by a sub-equatorial climate with low amplitudes of temperature (25-30°8C), high humidity (80-90%), two rainy seasons (April to July and October to November) and two dry seasons (December to February-March and August to September). The average annual rainfall is superior to 1600 mm [2].

The plant material used consisted of six *Hevea brasiliensis* (Mueller Argoviensis, Euphorbiaceae) clones. These included two clones received from Malaysia (PB 310 and PB 280), three clones created in Côte d'Ivoire (IRCA 202, IRCA 331, IRCA 707) and GT1 (Table 1). Clone GT 1, which is the most widely grown clone in Côte d'Ivoire, was used as control. It is a primary clone (from a mass selection) originating from Indonesia, specifically Java (Gondang Tapen). Its growth is moderate before tapping and low after taping [17,18,19]. It is a hardy clone whose average yield per tree and per tapping is offset by its good homogeneity, its average sensitivity to tapping panel dryness and its equally acceptable resistance to wind damage [17]

2.2. Methodology

2.2.1. Experimental design and treatments

The experimental design used was a Fischer block of 6 treatments (clones) and 4 replications. Each clone was represented by 448 trees. The planting density was 510 trees per hectare (7m X 2.8m).

The tapping started when at least 50% of trees reached a girth of 50 cm at 1 meter above ground.

The trees were tapped in downward half-spiral for 10 years and in upward quarter-spiral for 4 years. The tapping was carried out every four days, 6 working days out of 7 (S/2 d4 6d/7). The trees were stimulated 10 times per year with a stimulant paste obtained by mixing Ethrel and palm oil to get final concentrations of 2.5 and 5% active ingredient (Etephon) respectively in downward and upward tapping. (S/2 d4 6d/7 ET2.5% Pa1(1) 10 y; S/4 d4 6d/7 ET5% Pa1(1) 10/y).

2.2.2. Measurements made

2.2.2.1. Agronomic parameters

- **Rubber yield**

Rubber yield was assessed per treatment. The coagulum, removed at the next tapping, was collected, weighed monthly (fresh weight, P.F.) and stored. The transformation coefficient, the dry rubber percentage of a given fresh rubber sample, was used to calculate the dry rubber yield for each pattern. It was calculated from one coagulum sample per treatment. Each sample was weighed, creped, dried at 80°C in an oven for 24 hours and reweighed. Dry rubber yield was expressed in kilograms per hectare per year (kg/ha/yr).

- **Isodiametric growth of the trunk**

Clone vigor was assessed from trunk girth measurements. The measurements were made once a year using a tape measure. They were made at 1m above ground for untapped trees and at 1.70m for trees under tapping. The average annual increment was expressed (cm/year).

- **Tree stands**

The number of tappable trees was assessed before tapping commencement. Then, an inventory of the number of trees was made at the end of each physiological year.

2.2.2.2. Measurements of latex physiological parameters and Sensitivity to tapping panel dryness

The most important latex physiological parameters, due to their involvement in the mechanisms related to rubber yield, were analyzed once a year, in November. These included dry rubber content, sucrose, inorganic phosphorus and thiol group contents of the latex. Some latex collected by needle under the tapping cut (downward tapping) and above the tapping cut (upward tapping), according to the "latex micro diagnostic" method (MDL, Jacob *et al*., 1988), made it possible to determine the values of the physiological parameters.

- **Measurement of dry rubber content**

The rate of dry matter in the latex was determined by weighing 1 ml of fresh product in a 10 ml pillbox, before and after steaming at 80°C for 24 hours.

- **Determination of sucrose, inorganic phosphorus and thiol compounds**

The sucrose, inorganic phosphorus and thiol group contents were determined from the TCA serum obtained after coagulation of the latex in trichloroacetic acid (TCA). These contents, expressed in millimoles per liter of latex ($mmol.l^{-1}$), were determined by the anthrone method developed by [20] Ashwell (1957), the method of [21]Taussky and Shorr (1953) and the method of [22] Boyne and Ellman (1972) respectively for sucrose, inorganic phosphorus and thiol groups. The interpretation of physiological parameter values took into account the reference values defined by [23] Jacob *et al*., 1987.

- **Visual estimate of tapping panel dryness**

The quick survey method by visual estimate helps report the appearance and progress of tapping panel dryness [24]. To each tapped tree, a number, proportional to the tapping cut length affected by tapping panel dryness, ranging from 0 to 6, was assigned. For each plot, the precise count of the condition of the trees was performed and the rates of total length of diseased cut (LEM%) were calculated.

2.2.3. Statistical analyses

Data on rubber yield, isodiametric growth of the trunk, stand, micro diagnostic latex and tapping panel dryness survey were processed using STATISTICA 7.5 statistical software. An analysis of variance was performed and the significance level of the differences between the averages was estimated by the NEWMAN-KEULS test at 5% threshold. For the comparison of percentages, the average comparison test using the least significant difference (ppds) at 5% threshold was carried out.

3. Results

3.1. Agronomic parameters

3.1.1. Dry rubber yield

Rubber yield in g/t/t varied significantly depending on the clone in downward as well as in upward tapping (Table 2). In downward tapping, clones IRCA 331 and PB 310 recorded the best rubber yields statistically identical to each other and significantly higher than those of the other clones. They were 72 g/t/t and 65 g/t/t, respectively for clone IRCA 331 and PB 310. In downward tapping, clone IRCA 331 had a yield of 138 g/t/t statistically higher than those of the other clones which recorded statistically equivalent yields.

As for productivity expressed in kg/ha/yr, the analysis of variance of the average dry rubber yields, in downward tapping, showed

that clone IRCA 331 got the best yield with 2638 kg/ha/yr significantly higher than those of the other clones. Clone GT 1, control, had an average annual dry rubber yield of 1622 kg/ha/yr statistically equivalent to those of clones PB 280 and IRCA 202. Clone IRCA 707 recorded the lowest level of rubber yield with 1035 kg/ha/yr. The yield gain relative to the control (GT 1) was 63% for clone IRCA 331 (Table 2). In upward tapping, the annual average dry rubber yields were significantly improved for all the clones except clone PB 310 which experienced a decrease in yield compared to downward tapping. Clone IRCA 331 had a rubber yield of 4900 kg/ha/yr significantly higher than those of the other clones. Compared with the control, GT 1, the productivity gain generated by clone IRCA 331 was in the order of 80% while the other clones experienced productivity losses. The lowest rubber productivity was recorded with clone IRCA 707 (Table 2).

3.1.2. Isodiametric growth of tree trunks

During the immature stage, the annual rate of tree trunk girth increment ranged from 9.13 to 10.18 cm/yr. Clones GT 1 (9.13 cm/yr) and IRCA 331 (9.43 cm/year) showed statistically identical and significantly lower girth increment values than those of the other clones (Table 3).

The average annual tree trunk girth increment, after tapping commencement, was significantly reduced and varied from 2.25 to 3.80 cm/yr regardless of the clone studied. Clone IRCA 331 showed an average annual increment statistically identical to that of the control, clone GT 1. The values were 2.62 cm/yr for clone GT 1 and 2.56 cm/yr for clone IRCA 331. Clones PB 310, PB 280 and IRCA 202, respectively, had average annual increments of 3.80 cm/yr, 3.31 cm/yr and 2.95 cm/yr. The lowest increment was obtained with clone IRCA 707 showing an average annual increment of 2.25 cm/year (Table 3).

3.1.3. Stand evolution

The analysis of the evolution of the number of trees tapped during the 14 years of experiment reveals an increase from the first to the third year for all the clones studied except clone IRCA 707 which experienced a fall of stand from the second year. Apart from clones GT1 and IRCA 331 which kept their stand above 460 trees tapped up to the end of the trial, the other clones had their stand of tapped trees degraded over time. Clones IRCA 202, IRCA 707 and PB 310

showed the lowest stand levels at the end of the experiment (Figure 1).

3.2. Physiological parameters of the latex and Sensitivity to tapping panel dryness

3.2.1. Dry rubber content

The average dry rubber contents (Ex.S) of trees' latex ranged from 44.92 to 50.88% depending on the clone after 14 years of experiment (Table 4). The rates were very high regardless of the clone studied. The highest dry rubber contents were obtained with clones IRCA 331, PB 310, PB 280 and GT 1 which were respectively 50.88; 50.72; 50.43 and 49.02%. These contents were statistically equivalent to each other and significantly higher than those obtained with clone IRCA 707 (Table 4).

3.2.2. Sucrose content

The average sucrose (Sac) contents of rubber trees' latex statistically varied from 7.97 $mmol.l^{-1}$ (average) to 15.02 $mmol.l^{-1}$ (very high) depending on the clone studied (Table 4). Clone IRCA 331 had a sucrose content of 12.40 $mmol.1^{-1}$ statistically identical to those of clones IRCA 707 (15.02 $mmol.l^{-1}$) and GT 1 (10.36 $mmol.l^{-1}$).

3.2.3. Inorganic phosphorus content

The average inorganic phosphorus (Pi) contents of rubber trees' latex ranged from 11.87 $mmol.l^{-1}$ (low) to 26.13 $mmol.l^{-1}$ (very high) depending on the clone (Table 4). Clone IRCA 331 had an average Pi content of 16.84 $mmol.l^{-1}$ statistically identical to that of the control, GT 1, which recorded 18.74 $mmol.l^{-1}$. These were average and significantly lower than those of clones PB 280 and PB 310, which were, respectively, high (22.31 $mmol.l^{-1}$) and very high (26.13 $mmol.l^{-1}$; Table 4).

The physiological profile of clone IRCA 331 trees during the experiment was the most balanced relative to the trees of all the other clones.

3.2.4. Thiol group contents

The average thiol group contents (R-SH) of rubber trees' latex ranged from very low (0.38 $mmol.l^{-1}$) to average (0.73 $mmol.l^{-1}$). Clone IRCA 331 had an average thiol content (0.73 $mmol.l^{-1}$) that was statistically identical to that of the control GT 1 and clone IRCA 707 (Table 4).

3.2.5. Sensitivity to tapping panel dryness

The diseased cut length rates expressed by the trees varied significantly depending on

the clone (Table 5). Clones IRCA 331, GT1 and PB 280 got the lowest average rates of diseased cut length. These were 4.01, 4.76 and 4.89% respectively for clones IRCA 331, PB 280 and GT 1. Clones IRCA 202, PB 310 and IRCA 707 were the most sensitive to tapping panel dryness syndrome with, respectively, 10.46, 12.61 and 16.90% (Table 4).

4. Discussion

Clone selection in Côte d'Ivoire is mainly focused on rubber yield potential. This potential is guaranteed by good vegetative growth and medium to high initial yield. This should, however, be maintained and even improved over time, thanks to a favorable response to exogenous hormonal stimulation, a good resistance to the factors of reduction of the number of tapped trees which are wind breakage and tapping panel dryness. Growth data from the assessed clones indicate that during immature stage, clones GT 1 and IRCA 331 had statistically identical and significantly lower vigor than those of the other clones. The average annual girth increment of clone IRCA 331 decreased from 9.43 cm at immature stage to 2.56 cm during tapping.[25] have shown that rubber tree latex harvesting is always accompanied by a drastic reduction in the annual rate of vegetative growth [16, 26,27] which switches from [9-10 cm.] to [1.0-3.5 cm]. This decline in the growth rate can be explained by the fact that there is a metabolic partition of the developed energy and photosynthates by the plant during the yield stage. Indeed, several authors [16,28, 29,30] have shown, in mature tapped rubber tree, the existence of a strong competition between radial vegetative growth and rubber yield, to the detriment of radial vegetative growth in an estimated ratio of 1 to 2.25 [26]. Apart from the special cases of clone IRCA 707 which, despite its low productivity, showed the lowest growth and that of PB 280 which, with good productivity, showed the 2nd best vegetative growth, our results clearly illustrate the antagonism existing between rubber yield and vegetative growth. Because clones IRCA 331, GT 1, IRCA 202 and PB 310 showed an order of rubber productivity perfectly opposite to that of radial vegetative growth.

Moreover, clone IRCA 331 had a significantly higher rubber yield than the others during the experiment. Compared to the reference clone, GT1, it showed a yield gain in the order of 63% in downward tapping and 80% in upward tapping. This good yield level could be explained, on the

one hand, by the fact that this clone has a significant intrinsic yield capacity, and on the other hand by the fact that the applied latex harvesting technology allowed clone IRCA 331 to best express its potentialities. This was not the case for clone PB 280 which could not keep in the long term its good yield level in downward tapping (initial). In fact, compared to the reference clone, the productivity gains of PB 280 and PB 310 switched from 113% and 129% in downward tapping to 94% and 64% in upward tapping. This difference in productivity with respect to GT 1 might be due to a physiological fatigue related to the high stimulation intensity of these clones belonging to the class of fast metabolic activity; this is the phenomenon of overstimulation [16]. In contrast, clone IRCA 331, which improves its rubber yield level over time, seems better able to bear the regime of ten annual stimulations to be applied to it. Furthermore, unlike other clones that had their stand of tapped trees degraded over time, clone IRCA 331 and the reference control kept a good tappable tree stand until the end of the experiment. Our results also show that clones IRCA 331, GT 1 and PB 280 expressed a low sensitivity to tapping panel dryness, a good keeping of tappable rubber tree stand unlike clone PB 280 whose stand was quite good. This shows their good resistance to the factors of tappable tree stand reduction. The stability of the tree stand observed in these clones shows their low sensitivity to the main factors of stand reduction that are tapping panel dryness and wind damage [8,9,10,11]. Indeed, the results showed that clones IRCA 331 and GT1 were among the clones having obtained the lowest average rates of diseased tapping cut length. Several authors [8,31,32,33] have reported that tapping panel dryness rate increases with the frequency of stimulation. This suggests that these clones could better bear the applied stimulation regime compared to clones PB 310, IRCA 707, IRCA 202, and PB 280 that were sensitive to one or the other of the major factors of stand reduction. The productivity performance and the low sensitivity to tapping panel dryness of clone IRCA 331 are also due to its good physiological profile, which is expressed first of all by a high dry rubber content reflecting an efficient rubber biosynthesis within the latex vessels [34,35]. Then, by a rather high sucrose content which shows that the raw material needed for rubber synthesis remains available despite its high yield [24]. Indeed, this content is a reflection of the activation of latex-producing metabolism as sucrose is the raw

material of isoprene biosynthesis [36]. This is fully confirmed with clone IRCA 331 and, to a lesser extent, clone GT 1, that showed good yield levels. However, the low yield level of clone IRCA 707, despite high sucrose content, suggests a less efficient use of sugar in latex vessels.

The average inorganic phosphorus content, reflecting the intensity of energy metabolism and rubber synthesis, as well as the average content suggest that this clone could still bear a more intense tapping or stimulation regime. This is confirmed by the average thiol group content that allows it to bear the stresses associated with stimulation. Indeed, thiols (R-SH) reflect the antioxidant potential of latex; they make it possible to fight against senescence phenomena generated by oxidation mechanisms all the more active as the metabolic activity is intense [37].

5. Conclusion

At the end of this study, which was conducted in order to test newly developed clones, it appears that clone IRCA 331 proves to be a clone with interesting agronomic and physiological characteristics for an improvement in the national rubber productivity. It is characterized by an average vigor comparable to that of GT1, the reference control. Compared to clone GT1, clone IRCA 331 makes it possible to have a rubber productivity gain in the order of 63% in downward tapping and 80% in upward tapping. Its good physiological profile, characterized by average inorganic phosphorus, sucrose and thiol contents despite 14 years of intensive regime, allows it to bear high stimulation intensities. Clone IRCA 331 is not very sensitive to the main factors of stand reduction which are tapping panel dryness and wind breakage.

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Table 1: Geographical and genetic origin of the clones tested

N°	Clones	Geographical origin	Genetic origin
1	IRCA 707	Côte d'Ivoire	PB 235 x MDF 38
2	GT 1*	Indonesia	Primary clone
3	IRCA 202	Côte d'Ivoire	GT 1 x RRIM 605
4	IRCA 331	Côte d'Ivoire	GT 1 x RRIM 600
5	PB 280	Malaysia	PBIG x Seedling
6	PB 310	Malaysia	PB 5/51 x RRIM 600

* Reference clone in Côte d'Ivoire used as a Control.

Table 2: Average dry rubber yield of the studied clones

Clones	Downward tapping			Upward tapping		
	g/t/t	kg/ha/yr	%GT1kgha	g/t/t	kg/ha/yr	%GT1kgha
IRCA707	34 c	1035 d	64	56 b	1384 d	51
IRCA202	46 b	1555 c	96	65 b	1779 cd	65
GT1	**46 b**	**1622 c**	**100**	76 b	**2720 b**	**100**
PB280	53 b	1833 bc	113	82 b	2546 bc	94
PB310	65 a	2088 b	129	68 b	1732 cd	64
IRCA331	72 a	2638 a	163	138 a	4900 a	180

In the same column, the averages followed by the same letter are not significantly different (Newmann-Keuls test at 5%).

Table 3: Tree trunk girth increment

Clones	Average annual increment (cm/yr)	
	Immature stage	**Mature stage**
IRCA 707	9.87 a	2.25 e
IRCA 202	9.98 a	2.95 c
GT 1	**9.13 b**	**2.62 d**
PB 280	9.89 a	3.31 b
PB 310	10.18 a	3.80 a
IRCA 331	9.43 b	2.56 d

In the same column, the averages followed by the same letter are not significantly different (Newmann-Keuls test at 5%).

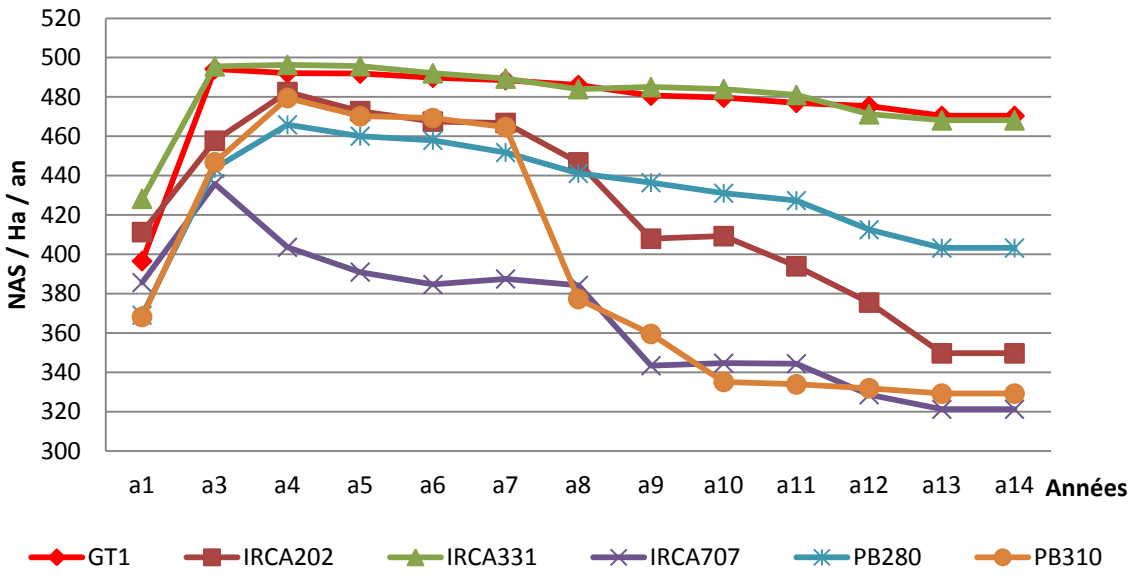

Figure 1: Evolution of the number of tapped trees during the experiment

Tableau 4: Physiological parameters of the studied clones

Clones	ExS (%)	Sac (mmol.l^{-1})	Pi (mmol.l^{-1})	RSH (mmol.l^{-1})
PB 310	50.72 a	7.97 c	26.13 a	0.57 bc
PB 280	50.43 ab	8.11 c	22.31 b	0.38 d
IRCA 202	47.44 bc	8.29 c	19.40 bc	0.43 cd
GT1	**49.02 ab**	**10.36 bc**	**18.74 c**	**0.61 ab**
IRCA 331	50.88 a	12.40 ab	16.84 c	0.73 a
IRCA 707	44.92 c	15.02 a	11.87 d	0.60 ab

In the same column, the averages followed by the same letter are not significantly different (Newmann-Keuls test at 5%).

Tableau 5: Tapping panel dryness rate

Clones	ES (%)
IRCA 331	4.01 c
PB 280	4.76 c
GT 1	**4.89 c**
IRCA 202	10.46 b
PB 310	12.61 b
IRCA 707	16.90 a

In the same column, the averages followed by the same letter are not significantly different (Newmann-Keuls Test at 5 %).